GUIDE BOOK No. 4

EXCURSIONS

IN

SOUTHWESTERN ONTARIO

GEOLOGICAL SURVEY
DEPARTMENT OF MINES
OTTAWA
1913

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EXCURSIONS

IN

Southwestern Ontario

(Excursions A 4, B 1, A 12, B 3.)

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EXCURSIONS IN SOUTHWESTERN ONTARIO.

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EXCURSIONS A 4 AND B 1.

NIAGARA---IROQUOIS BEACH

BY

F. B. Taylor

AND

A. P. Coleman.

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General view of Niagara Falls, looking south from the west end of the Park bridge.

NIAGARA FALLS AND GORGE.*

(EXCURSION B 1.)

BY

FRANK BURSLEY TAYLOR.

GENERAL RELATIONS OF THE NIAGARA DISTRICT.

NIAGARA DISTRICT DURING THE TIME OF THE LAST ICE SHEET.

During the maximum extent of the last or Wisconsin ice sheet, Niagara district lay under about 3,000 feet (900 m.) of ice and was in or near the axis of the main ice current which moved southwestward through the basins of Lakes Ontario and Erie. One of the most pronounced re-entrants of the ice front at that time was at Salamanca, N.Y., about 67 miles (107 km.) south of Niagara Falls. The general level of the hills around Salamanca is 1,800 to 2,000 feet (550 to 600 m.) above sea level, and from this place to Niagara Falls the surface of the ice rose probably not less than 1,500 feet (450 m.). The altitude of the general surface at Niagara Falls is nearly 600 feet (182·9 m.) above sea level, indicating therefore, a thickness of ice approximating 3,000 feet (900 m.).

The Niagara district remained continuously under the burden of ice, not only during the entire time that the front of the ice sheet was retreating from a point about 10 miles (16 km.) north of the Ohio river at Cincinnati to Niagara Falls, but during an equally long time, probably, in the advancing phase. As the ice front retreated northeastward in the Lake Erie basin, glacial waters followed it and covered the lower ground as fast as the ice withdrew. For a short time after the ice had uncovered the present site of Niagara gorge the lake waters still covered this district, but when it had retreated to a position probably about at the present shore of Lake Ontario north of Lewiston, a lower outlet was opened on the northward sloping hills south of Syracuse, N. Y., and the waters

*The material for this Guide Book, so far as it relates to Niagara Falls and Gorge, is taken mainly from the unpublished manuscript of the Niagara Folio, to be published by the United States Geological Survey, and is used with the permission of the Director.
(Mr. Taylor's text was written before the field and office studies were completed, and he has had no opportunity of reading the proof.—ED.)

in the Lake Ontario basin were drawn down to a level somewhat lower than the present level of Lake Erie. This inaugurated the flow of Niagara river and completed the separation of Lake Erie from Lake Ontario. Niagara Falls then began the work of making the gorge at the escarpment south of Lewiston.

PHYSIOGRAPHIC DEVELOPMENT.

Niagara district lies between Lake Erie and Lake Ontario, in the midst of a region which has the physiographic and geologic characteristics of an eroded, ancient coastal plain. Following the deposition of the Paleozoic sediments, the region as a whole was raised out of the sea about at the close of the Paleozoic era and appears to have been a land surface ever since. In so great a length of time the region has, of course, been extensively modified by subaërial and stream erosion, but it does not appear to have been affected by marine denudation. The highlands of Canada are the oldland, and the beds of the ancient coastal plain dip gently southward from it. Some of these beds are soft and others hard, and in consequence of this difference the softer beds have been reduced to lowlands, while the harder beds remain as uplands of relatively low relief. Thus, through the effects of erosion, the ancient coastal plain has become a belted plain composed of a series of narrow, nearly flat plains separated by northward facing escarpments, like a flight of steps descending to the north. But the tread of each step slants gently backward towards the south and produces the form which in New Mexico is called a cuesta, meaning a low ridge, steep on one side, but with a gentle slope on the other.

South of the oldland lies the Ontario lowland, and the basins of Lake Ontario and of Georgian bay are excavated in it. To the south of this lies the Niagara cuesta with its strongly marked escarpment facing northward over the Ontario lowland and Lake Ontario. South of Lake Erie and extending eastward through New York lies the Alleghany cuesta. It has been customary in the small scale maps usually employed, to recognize only one simple lowland as occupying the whole space between the Niagara and Alleghany cuestas, and this has been called the Erie lowland. But when the region around Niagara is studied

in more detail and represented on a larger scale, another less pronounced cuesta and lowland are found to lie between, and their relations to Niagara history increase their present importance. These are the Onondaga cuesta, formed on the outcropping ledges of the Onondaga limestone, and the Huron or Tonawanda lowland north of it. The Tonawanda and Chippawa valleys and the deeper trough of Lake Huron are in this lowland. This division of the belted area restricts the application of the name Erie lowland to the lowland belt which lies south of the Onondaga escarpment and in which lies the bed of Lake Erie. In the early history of Niagara river the Tonawanda lowland was occupied by a temporary lake about 50 miles (80 km.) long and 1 to 7 miles (1·6 to 11·3 km.) wide. Lake Tonawanda covered the lower ground around the city of Niagara Falls and extended east about 40 miles (64 km.) and west 10 miles (16 km.) into Canada.

ORIGIN OF DRAINAGE SYSTEM.

In the early development of drainage on the newly elevated coastal plain, the master streams probably flowed south or southwest over the Great Lakes region and were, as Grabau has said, consequent streams, their course being determined by the direction of the original slope. Subsequent streams began immediately cutting valleys along the lines of the weaker strata at right angles to the main streams, and these side streams ultimately combined and developed a system which became dominant. The final stage in which the deeper lake basins were excavated and the land surface prepared for the Great Lakes and for inter-glacial Niagaras, as well as the modern Niagara, was probably accomplished chiefly after the original drainage system had been broken up and had ceased to be dominant.

STRATA IN NIAGARA GORGE.

The ancient belted plain, with its parallel features of relief, was the ground over which Niagara river began to flow when it first came into existence, and it is into this plain that the cataract has sawn the great canyon. North of Lewiston there was no capping hard layer to produce

a vertical fall; the banks are composed of soft red shale and are relatively low. The gorge begins at the escarpment south of Lewiston. From this place to the present falls the arrangement of the strata favoured the continuous existence of a vertical cataract, except at the Whirlpool which was filled with loose glacial drift. The hard, massive bed of the Lockport (Niagara) limestone forms the capping layer and increases in thickness from less than 20 feet (6·06 m.) at the escarpment to about 80 feet (24 m.) at the Horseshoe Falls, 130 feet (40 m.) at the first cascade above the falls and about 250 feet (76 m.) in well borings farther south. At the lower levels the Clinton limestone, with the Medina (upper Medina) sandstone close below and the Basal or Whirlpool sandstone of the Cataract (Medina) formation are hard, but they are relatively thin. The rest of the strata are mainly soft shales, but with occasional thin, sandy, harder beds.

The strata through which the gorge is cut appear to the eye to be horizontal, but in reality they dip toward the south at a nearly uniform rate of 20 feet to the mile (3·8 m. per km.). There are slight variations from this rate, most notably near the mouth of the gorge, where the dip for some distance is slightly greater. From the mouth of the gorge to the Horseshoe Fall all of the strata decline southward 130 to 140 feet (36·6 to 42·7 m.).

The next important hard layer below the Lockport is the Clinton limestone which is about 20 feet (6 m.) thick and forms a distinct bench along the sides of the gorge at some places. Spencer, finds only 12 feet (3·6 m.) of the Clinton limestone above water at the Horseshoe Fall. At Foster's flats the Clinton forms the prominent bench next below Wintergreen terrace and many of the great, fallen blocks rest upon it.

The only other hard layer of importance is the Whirlpool sandstone, which is on the average about 25 feet (7·6 m.) thick. At the mouth of the gorge the top of this sandstone is 142 feet (43·3 m.) above Lake Ontario. At Foster's flats it is about 75 feet (23 m.) above the lake and forms the floor of the flats and of Niagara glen and its bottom is at the waters edge at the head of Foster rapids. At the whirlpool it forms a bench a few feet above the water and is most accessible on the east side below Whirlpool point. Farther south it passes beneath the level of the river. The surface at the whirlpool

is about 47 feet (14·3 m.) above Lake Ontario, so that the sandstone declines about 80 feet (24 m.) from the mouth of the gorge. On the west side opposite the American fall, a bench disclosed by Spencer's soundings at 90 to 100 feet (27 to 30 m.) is presumably of this sandstone, indicating a descent of about 50 to 60 feet (15 to 18 m.) from the whirlpool to the falls, for the water surface at the base of the falls is about 100 feet (30 m.) above Lake Ontario.

THE PROCESS OF GORGE MAKING.

The gorge is being elongated by boring at the base of the falls, where the heavy mass of falling water strikes at the end of its vertical descent. The softer strata are slowly worn away by the impact of the water itself, but the hard capping layer is removed chiefly by undermining, until it falls away in huge blocks. The blocks which drop into the caldron at the foot from above become highly efficient tools for grinding away the shale, for no doubt many of them are spun around in the violent currents like pestle stones in the making of potholes. The limestone is much harder than the shale, and while the spinning undoubtedly wears away the blocks, it wears away the shale in the walls and bottom of the caldron much faster.

When the falls had large volume and full height, the thinner, hard layers were bored through and removed, but when the height of the falls was reduced, as it was in one part of the gorge, or where the water sheet passing over the crest became thin, as it did in several places, parts of these beds were not removed and now form benches or terraces of more or less extent as described above. When the volume of the river was relatively small, as it was in two sections of the gorge, these layers were not both bored through by one vertical plunge, but in all probability formed separate cataracts, one for each hard layer. As Spencer has pointed out, this was probably the condition for a time in the older part of the gorge, north of Niagara University. In the gorge of the Whirlpool rapids the Clinton limestone probably formed a separate fall, but the Whirlpool sandstone was not bored through, except towards the north end, and probably now forms the block-covered floor of the channel. At

the head of the narrow gorge the sandstone, as suggested by the dip, is 70 feet (21·3 m.) or more below the surface.

After the relatively narrow, shallow sections of the gorge had been made by the small cataracts, the rush of the large-volume river through these sections deepened them still further, not by the action of vertical cataracts, but by the slower and very different process of chute or rapids erosion. The deepening of the Old Narrow gorge north of the University has been substantially completed in this way; that of the gorge of the Whirlpool rapids is now in progress.

RELATIONS OF THE GREAT LAKES TO NIAGARA HISTORY.

Having in mind the foregoing outline of the geological conditions under which the gorge was made and of the physical processes involved, it is important to review briefly the relations of the Great Lakes to the history of Niagara river.

Excepting a few small streams which enter Niagara river above the falls, all the water in the river comes from the Great Lakes above. During two periods the discharge of Lake Erie alone passed over the falls; at other times the full discharge of the four upper lakes. During one period the full four-lake discharge was considerably increased. The lakes are simply storage reservoirs and act as equalizers of flow and Niagara river is merely the overflow of these great reservoirs. On this account the river is characterized by a steadiness and uniformity of volume found in few rivers. It has a slight annual variation of volume, due to spring freshets which raise the level of the lakes and summer droughts which lower their levels, through a total range of about two feet (·61 m.) and it has a longer period of variation amounting to three or four feet (·91 to 1·21 m.) and corresponding roughly to the eleven year wet and dry periods which vary with the frequency of sun spots. Considerably larger variations are caused by cyclonic storms on Lake Erie and by ice jams in the river itself. A heavy southwesterly gale of unusual duration has been known to raise the level of the water at Buffalo nearly eight feet (2·44 m.) and a similarly severe northeasterly gale has lowered it nearly six feet (1·38 m.) making a total variation of about 14 feet (4·27 m.) in the depth of the water at the head of Niagara

river. The great ice jam of February, 1909, held the water back so that the American fall went almost entirely dry and the Horseshoe fall was greatly reduced. Niagara river knows no such thing as the great floods that affect rivers like the Ohio and the Mississippi. The shorter periodic variations (annual, eleven year, etc.) are much too slight in amount and also too short in duration to find any expression in the dimensions of the gorge.

When carefully studied in detail, the gorge is found to show certain parts that are relatively wide and deep and others that are relative narrow and shallow, and these sections vary in length from 2,000 feet (600 m.) to $2\frac{1}{4}$ miles (3·6 km.) and are therefore much too large and required vastly too long a time in their making to be referred to anything like the brief and small variations suggested above.

It might be thought that variations of geological structure or lines of weakness in the rocks have been a principal cause of variation in the dimensions of the gorge, but this is surely not so in any important degree. The geological structure throughout the length of the gorge is remarkably uniform. Except the thickening of the capping limestone in going from Queenston to the falls, no variation of structure or lines of weakness are known that would produce a perceptible effect. In the present stage of investigations it does not seem possible to estimate accurately the effect of this variable factor. Its importance, however, dwindles to almost nothing in comparison with a certain other variable factor which has surely been the one great cause of variation in the dimensions of the gorge: variation in the volume of the river.

Beginning at the mouth of the gorge and noting its dimensions, especially its width at the top of the cliffs, any one may easily recognize four clearly defined sections or divisions, not including the whirlpool which lies in a re-excavated portion of the much older, buried St. David gorge. But as a matter of fact there are five sections, the first two occupying the oldest part of the gorge, that between its mouth and Niagara university. The two together are nearly one and a half miles (2·4 km.) long. The remaining portion of the gorge shows three divisions very distinctly. The first is a wide section, the lower part shallow and the upper part deep, extending from the bend at Niagara university up to the upper side

of the Eddy basin (excluding the whirlpool). This is about two miles (3·2 km.) long. Then comes the narrow, shallow section of the gorge of the Whirlpool rapids, three fourths of a mile (1·2 km.) long, and finally the wide deep section which the falls are now making, two and one fourth miles (3·6 km.) long. Knowing the uniformity of the geological structure, these variations of width and depth suggested to Mr. Gilbert many years ago the possibility of a variation of volume as the cause. The truth of this interpretation could hardly be fully established from a study of the gorge characters alone, but it might be expected that either strong corroboration or disproof of it would be found in the history of the four Great Lakes which now discharge their surplus waters through Niagara river. A brief statement of that part of the Great Lakes history which is related to Niagara river will show how many and how great have been the variations of its volume and the order of their occurrence.

OUTLINE OF THE GREAT LAKES HISTORY SINCE THE BEGINNING OF NIAGARA FALLS.

THE SUCCESSION OF THE GREAT LAKES.

Since Niagara falls first began, the great lakes have passed through five stages of change. Each of these stages had a different outlet from that of the stages immediately preceding and following it, and the volume of water discharged through Niagara river changed with each change of outlet. The five lake stages were as follows:

1. Early Lake Algonquin.
2. Lake Algonquin, Kirkfield stage.
3. Lake Algonquin, Port Huron stage.
4. The Nipissing Great Lakes.
5. The Present Great Lakes.

Four of the great lakes, including lakes Superior, Michigan, Huron and Erie, lie above Naigara and discharge their waters through it at the present time. But

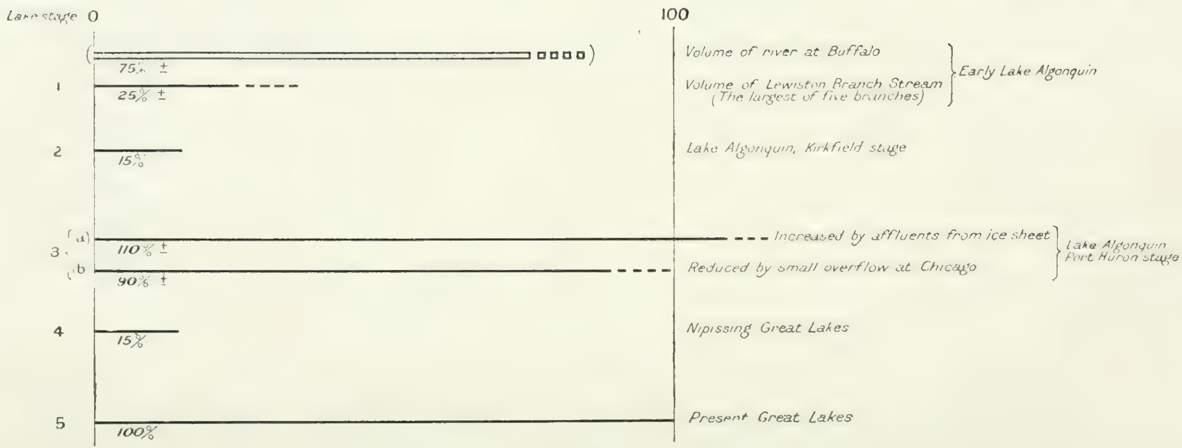

Diagram showing variations in volume of Niagara river.

at two different times in the past the first three of these lakes discharged their whole overflow by another route, not passing through Niagara. Taking the lake stages in the order of their occurrence as named above, and noting the lake area and the approximate frontage of the ice sheet involved in each, with the location of the outlet, the causes and times and approximate amounts of variation of the volume of Niagara river are clearly and fully revealed.

1. Early Lake Algonquin.—This lake occupied the south half of the Lake Huron basin and received a large affluent from smaller lakes in the south part of Georgian Bay basin and the Lake Simcoe basin. The ice barrier spanned Lake Huron from side to side and nothing was received during this stage from the Lake Michigan or Lake Superior basins. The volume of discharge was relatively large however, for the lake and its affluents all received large tributaries directly from the ice sheet all along their northern sides. The outlet of early Lake Algonquin was southward through St. Clair and Detroit rivers to Lake Erie and the discharge through Niagara river was correspondingly greater than that from Lake Erie alone. The whole volume of Niagara river at that time was probably nearly if not quite as large as it is now.

2. Lake Algonquin, Kirkfield stage.—This lake occupied the basins of Lakes Superior, Michigan and Huron and some of the low-lying lands bordering upon them. It did not attain its full extent in this stage, however, because the ice barrier still occupied large areas along its northern side. Thus, besides carrying the full discharge of the upper three lakes, Lake Algonquin at this stage received a large inflow of water directly from the ice sheet, and its total discharge was therefore in all probability slightly greater than the volume of the present St. Clair river. The outlet was at Kirkfield, Ontario, down the valley of Trent river to glacial Lake Iroquois, which was in part a contemporary of Lake Algonquin. The features of this outlet channel, caused by the scouring action of the great river, are strongly developed throughout its course and show unmistakably the great size of the stream.

3. Lake Algonquin, Port Huron stage.—At this stage Lake Algonquin covered nearly the same ground as before. The uplift of northern lands which changed the outlet from Kirkfield to Port Huron raised considerable

areas above the level of the lake, but a greater area was added by the progressive withdrawal of the ice sheet. During the first half of this stage, Lake Algonquin received a large inflow of water directly from the ice sheet which still formed an extensive barrier in the north. In the second half, the barrier had dwindled to so small a frontage that its contributions of water were relatively small and unimportant. In the first half of this stage there appears to have been a large discharge at Chicago as well as at Port Huron, but in spite of this the stream at Port Huron was apparently slightly larger than the present St. Clair river. The Toleston beach of the Lake Michigan basin appears to be the same as the Algonquin beach, indicating that the discharge in the first part of this stage must have been very large—so large that it seems hard to account for its excess of volume by affluents from the ice sheet alone. In the first half of this stage the volume of discharge at Port Huron was probably slightly larger than the volume of the present St. Clair river, but in the second half it was a trifle less, on account of a small discharge at Chicago, and the volume of Niagara river was affected in a corresponding manner.

4. Nipissing Great Lakes.—This stage of the upper lakes was inaugurated by the final withdrawal of the last remnant of the ice sheet from the Ottawa valley. These lakes occupied the three upper lake basins and covered an area only a trifle larger than that of the present lakes. The ice sheet having disappeared, no additional water was received from it and the volume of discharge was the same as the present volume of St. Clair river. The outlet during this stage was eastward from the northern part of the Georgian Bay region, its head being at North Bay, Ontario. The scouring effects of the outlet river are well marked in the valleys of the Mattawa and Ottawa rivers and indicate a river having the same volume as that of the present St. Clair river. During this stage, therefore, Niagara river was again left with only the discharge of Lake Erie.

5. The Present Great Lakes.—Continued uplift of northern lands raised the outlet at North Bay, Ontario, and sent the discharge of the three upper lakes to Port Huron and thence to Lake Erie and Niagara. In the transition, both outlets were active at once, but this arrangement did not last long. The change of outlet

to Port Huron brought the Nipissing great lakes to an end and inaugurated the present lakes. Thus, the present volume of Niagara river includes the entire discharge from the four lakes above, and this arrangement of overflow has continued ever since the last change of outlet.

INFLUENCE OF THIS SUCCESSION ON THE VOLUME OF NIAGARA RIVER.

The main facts of the lake history stated in the foregoing outline are all firmly established by observations, and the order of the lake stages, with their changes of outlet and the effects of these changes upon the volume of Niagara falls, are fixed beyond peradventure. The variations of volume are fixed primarily by the facts of the lake history, without any reference whatever to the characters displayed in the Niagara gorge. These facts are, therefore, the key to Niagara history and are far more weighty and reliable than any of the characters seen in the gorge; for no matter what characters are found there, it is certain, nevertheless, that the volume of Niagara river and the falls have varied as indicated by the lake stages and in the order named. With these facts in hand, the problem of correlation is relatively simple: can definite correlatives of lake stages be recognized in the gorge, and can *five* such correlative units, corresponding in character and order of occurrence to the five lake stages mentioned, be recognized?

The investigations of Dr. G. K. Gilbert and the writer of this text indicate that the correlation of gorge characters with the lake stages mentioned above is complete. The variations of volume of Niagara as deduced from the history of the great lakes may be represented graphically as in the accompanying diagram (p. 16).

Dr. J. W. Spencer also has contributed many valuable facts to the discussion of these subjects and was a pioneer in the study of the Great Lakes region. He named Lake Algonquin and, although its beach was already known in several places, its continuity and the rate and direction of its deformation in Ontario were first determined by him. He also named Lake Iroquois and made the first extended survey of its shore in Ontario. His views, differing from the views here expressed, sometimes with

regard to the meaning of facts, but mainly in the broader interpretations, may be found in his volume on the "Evolution of Niagara Falls" [**10**].

INFLUENCE OF THE ONTARIO BASIN ON NIAGARA FALLS.

The waters in the Lake Ontario basin have had an important influence on the early history of the falls and in the making of the older parts of the gorge. The history of Lake Iroquois and the succeeding waters of the Lake Ontario basin has not yet been fully worked out. There is a remarkable submerged terrace at the mouth of Niagara river known as Niagara bar, which has been supposed to be a delta of the river formed when the lake stood at a somewhat lower level. It is not certain that it is wholly of the nature of a delta. The shallower part extends about three miles (5 km.) out and six miles (9·6 km.) along shore; the deeper part five miles (8·0 km.) out and 15 to 20 miles (24 to 32 km.) along shore. Many soundings on it show "rocky" bottom. It is not known whether these indicate stranded blocks or ledges of bed rock in place.

The place of this formation in Niagara history is not yet definitely known, but it seems certain that it does not belong to the early time of Lake Iroquois. It seems more probable that such part of the deposit as is true delta corresponds to a recent lower level of Lake Ontario. On the other hand, it may be largely of inter-glacial age.

Faint remains of what is supposed to be the first or earliest shore of Lake Iroquois have been found north of Lockport and Lewiston, N. Y., at Hamilton, Ontario, and elsewhere, showing that Lake Iroquois first stood at a lower level than the well known Iroquois beach and was afterwards raised to the level of that beach by an uplift of the land in the region of the Iroquois outlet at Rome, N.Y. At Lewiston the level of the lake was raised about 50 feet (15 m.) and at its higher level stood 125 feet (38 m.) above the present level of Lake Ontario. The effect of this depth of water backing up into the gorge, was much the same as a reduction in the height of the falls, producing a corresponding decrease in the boring of the cataract as well as a higher level for the caldron bored out at the base of the falls.

At a later time the great ice barrier which spanned the St. Lawrence valley somewhere below Kingston and held Lake Iroquois up to the level of the Rome outlet, disappeared and the lake was drained off. The waters in the Ontario basin then fell much below the present level of Lake Ontario. This change revived the downward cutting of Niagara river, and the older parts of the gorge were then deepened by a moderate amount, but this was accomplished chiefly by the wearing action of rapids rather than by the boring of vertical falls. The effects of both the higher and lower stages of the waters of the Ontario basin upon the falls are seen in the gorge from its mouth up to the head of Foster flats.

Soundings in the Niagara gorge.

The U. S. Lake Survey made a number of soundings in Niagara river many years ago, but these were all confined to the upper great gorge from a point opposite the American Falls down nearly to Swift Drift point. All the other soundings within the gorge were made by Dr. Spencer, some of them under conditions of great difficulty. He made three attempts to sound the depth of the water at the base of the Horseshoe falls with two carefully protected Tanner-Blish sounding tubes. One of these attempts failed, but two of them appeared to be successful and he gives the results as 69 and 72 feet (21 and 21.9 m.) respectively. Considering the tremendous turbulence of the water at the base of the falls, however, there seems to be some doubt as to what might happen to the apparatus there. It seems quite as likely that it might be carried backward under the falls so as to strike the wall under the over-hanging ledge as that it should strike the bottom. Three soundings made at the head of the Whirlpool rapids give depths of 52, 86, and 68 feet (15.8, 26.2 and 20.7 m.) going eastward from the west side, and may be correct, but there is considerable possibility of error in this case also. The principal soundings will be referred to in the description of the gorge sections.

GEOLOGY OF NIAGARA GORGE.

At its head at Buffalo the Niagara river flows through a shallow passage in the Onondaga limestone of Devonian age. Thence northward to the falls and down the gorge to the head of Foster's flats all the visible exposures of strata belong to the Silurian system. Below this the only rock exposed is the Queenston shale of Ordovician age, and where not composed of glacial drift, the river banks from Queenston to Lake Ontario are composed of this shale. In a paper read before the Geological Society of America at New Haven, Conn., in December 1912, Prof. Chas. Schuchert of Yale University gave an account of recent investigations by himself, Dr. W. A. Parks of Toronto University and Dr. M. Y. Williams of the Canadian Geological Survey, in consequence of which a revision of the Silurian of the Niagara region is suggested. Prof. Schuchert has contributed the following brief statement of the Niagara gorge section :

NIAGARA GORGE SECTION.

Along line of New York Central railway and Grand Gorge trolley line (see Grabau, Bull. 45, N.Y. State Museum, 1901).

Silurian.

Lockport dolomite.—Thickness as exposed 130 feet (39.6 m.).

Rochester shale.—Thickness 68 feet (20.7 m.).

Clinton upper limestone with an occasional bryozoan reef at top (Irondequoit of Rochester, N.Y.). About 10 feet (3.05 m.) thick.

Crystalline, heavy bedded, highly fossiliferous, pinkish limestone. Fossils essentially those of the Rochester shale. Has zones of stylolites.

Clinton lower limestones—(Wolcott or Pentamerus lime-limestone at Rochester, N.Y.) About 15 feet (4.6 m.) thick.

Thinner bedded magnesian limestones with *Anoplotheca plicatula, Hyattella congesta*, etc.

Clinton shale.—About 5 feet (1.5 m.) thick.

Green to grayish shales with *Anoplotheca hemispherica* and *A. plicatula.*

Probable disconformity.

Medina formation.—Thickness 60 to 70 feet (18.3 to 21.3 m.).

Upper massive, quartzose, whitish, cross bedded sandstones. Gray band of authors. From 8 to 10 feet (2.44 to 3.05 m.) thick.

Reddish and greenish bedded sandstones, much cross bedded and channeled. From 12 to 15 feet (3.65 to 4.57 m.) thick. *Arthrophycus harlani* — 2 feet (.61 m.) beneath top — and *Lingula cuneata.* Thin bedded, reddish sandstones, with red shale partings and at least one zone of storm-rolled mud balls. From 35 to 40 feet (10.7 to 12.2 m.) thick. In the upper part of these sandstones occurs the typical Medina marine fauna.

Gray sandstone with green shale partings. Thickness 5 feet (1.5 m.). Poor Medina fossils.

Disconformity and irregular contact, seen best along the Grand Gorge trolley line.

Cataract formation.—To be seen on each side of the small tunnel on N.Y.C.R.R. Thickness about 51 feet (15.5 m.).

Upper dark green shales, 4 feet (1.2 m.) thick.

Thin bedded ,green to yellow magnesian and argillaceous limestone, in lenses abounding in *Helopora* and fragments of *Lingula.* Thickness 3 feet (.91 m.).

Middle green shales, 10 feet (3.05 m.) thick.

Thin bedded argillaceous magnesian limestones, 2 feet (.61 m.) thick.

Helopora common, *Leperditia, Whitfieldella* and fragments of *Lingula.*

Lower green shales, 7 feet (2.1 m.) thick.

Basal or Whirlpool (Grabau) sandstone. Thickness 25 feet (7.6 m.).

Hard, heavy bedded, gray, somewhat coarse, cross-bedded sandstones. Thin bedded in upper 5 feet (1.52 m.). No fossils.

Disconformity with irregular contact in places.

Ordovician.

Queenston (Grabau. Synonym *Lewiston,* Chadwick).

Brick-red sandy shales. Exposed for 115 feet (35.0 m.). No fossils. In Ontario in equivalent strata occur fossils of Richmondian age.

The equivalent strata of the older and newer classifications as used by Grabau and Schuchert respectively are shown in parallel columns below:

(Grabau)	(Schuchert)
Silurian	*Silurian*
Lockport (Niagara) limestone	Lockport dolomite
Rochester (Niagara) shale	Rochester shale
Clinton limestone, two beds	Clinton limestone, two beds
Clinton shale	Clinton shale
Medina formation	Medina formation
Upper Medina sandtone	Medina sandstone
	Cataract formation
Medina sandy shales	Cataract sandy shales
Lower Medina gray shales	Cataract gray shales
Medina gray, quartzose	Basal or Whirlpool sandstone
Whirlpool sandstone	
	Ordovician
Medina red shales	Queenston red shales
Oswego sandstone	Oswego sandstone
Ordovician	

The Lockport limestone is not rich in well preserved fossils where exposed in the Niagara gorge, but Grabau describes one of the lower beds of this foundation, the Crinoidal limestone, as a "highly crystalline limestone, on the weathered surfaces of which joints of crinoid stems and other organisms stand out in relief, particularly in the lower parts of the stratum. The rock is entirely composed of fragments of organisms which were ground up and mingled together in great profusion." The Geodiferous limestone next above also contains fragmentary fossils, but none well preserved.

Grabau gives also a list of the few fossils found in the Clinton upper limestone and 29 species found in the limestone lenses in the Clinton shale.

SUMMARY OF GORGE CHARACTERS AND SECTIONS.

If the study of the Niagara gorge were approached without any previous knowledge of the history of the great lakes, characters of some importance might possibly be overlooked, but the larger variations of width and depth would at once attract attention. From this point of view, the characters clearly suggest a division of the gorge into at least four sections, not including the whirlpool, and

there are other characters which more or less vaguely suggest a further subdivision of two of these sections. These subdivisions are indicated in the older two of the four more obvious divisions. One of these is confirmed by the lake history; the other is not. Beginning at the mouth of the gorge, one might conclude at a first glance that the first or oldest section extends all the way from the mouth of the gorge to the bend of the river below Niagara University and that this part of the gorge is therefore a unit in the river history. But such is not the case.

First or oldest Section. (Lewiston branch gorge.)

For about 2,000 feet (610 m.) south from the mouth of the gorge the cliff lines are somewhat irregular and the average top width is about 1,400 feet (430 m.) or about 100 feet (30 m.) greater than the remaining part extending to the university. Based on gorge characters alone, the reasons for making a division point here might perhaps seem insufficient. But in this case, other facts relating to the river history, as well as the greater weight of the lake history, established quite clearly the reality of a division point about at this place. In his studies of the Niagara gorge a number of years ago, Mr. Gilbert found that for a relatively short period Niagara river poured over the escarpment at five different places, the present place being the most westerly. The river, therefore, discharged only a fraction of its volume through any one channel, and yet three of the channels east of Lewiston indicate relatively large volumes. Altogether, the several channels seem to show clearly that the total volume of the river was nearly if not quite as large then as at present and certainly several times larger than the discharge of Lake Erie alone. It seems certain, therefore, that the irregularities and extra width of the first 2,000 feet (610 m.) of the gorge belong to the time of divided flow over the escarpment. In the lake history this correlates with the time of early Lake Algonquin.

The Old Narrow Gorge.

From this division point up to the bend below the university, the gorge is remarkable for the straightness of its cliff lines and the eveness of its top width. This is

known as the Old Narrow section and is a little more that a mile long. Its average top width is about 1,300 feet (400 m.). The talus slopes are fully twice as wide in these two old sections as the average in the newer sections. This is partly due to greater age and longer weathering, partly to thinner capping limestone and partly to the exposure of nearly 100 feet (30 m.) more of shale in the gorge walls here than in those above the head of Foster's flats. Spencer's soundings show a depth of 150 feet (45.7 m.) about 1,000 feet (304 m.) from the mouth of the gorge in the middle of the first section, but the Old Narrow section, judged by the few soundings available and by the behaviour of the water, is on the average less than 100 feet (30 m.) deep. In these older parts of the gorge the recent rise of the level of Lake Ontario has backed the water up into the gorge, slackening the current and increasing the depth. On this account the water stands somewhat higher and covers the lower part of the talus slopes. In the lake history this section of the gorge correlates with the Kirkfield stage of Lake Algonquin. It was originally made narrow and not so deep as now, for the cataract then carried only the discharge of Lake Erie, and Lake Iroquois stood about 75 feet (23 m.) higher than the present surface of Lake Ontario.

The Lower Great Gorge.

This section extends from the bend below Niagara university, where the gorge widens, to the upper side of the Eddy basin, but does not include the whirlpool. Its width between the cliff lines from the bend up to a point about 1,000 feet (30 m.) above the head of Foster rapids averages more than 1,600 feet (490 m.), and at the widest is about 1,825 feet (560 m.). It is also characterized by shallowness to the upper end of Foster's flat. Above the north end of Wintergreen terrace the width is 1,300 to 1,500 feet (400 to 460 m.), and shallowness gives place to greater depth at the upper end of Foster's flat. From the point of view of gorge characters alone, these variations of width and depth are not easily explained. But in the light of the lake history their causes seem clear, and although they might seem to furnish good ground for subdividing this section, the lake history shows that they are not of that order

of importance. The extra width was due partly to the augmented volume of the river (by water coming directly from the ice sheet) as compared with the present volume, and partly to the wide, flat rock floor above the falls, which caused the water sheet to be spread to unusual width. This last condition led to the formation of Wintergreen terrace and the associated lower rock terraces. The shallowness to the head of Foster's flat was caused mainly by the fact that Lake Iroquois stood 125 feet (38 m.) higher than the present level of Lake Ontario and backed up into the gorge at this level. The original narrowness and shallowness of the Old Narrow gorge just below must have tended to contribute to the same result until it was cut down by the scour of the rapids. The same uplift that raised the Kirkfield outlet sent the augmented discharge of the upper three lakes to Niagara, and it was then that the large-volumed cataract first began gorge making at the bend below the university. It also raised Lake Iroquois about 40 feet (12 m.), or from about 85 feet to 125 feet (25 to 38 m.) above present lake level. When Lake Iroquois fell to a lower level, the water at the base of the falls fell, and the falls immediately became in effect higher and bored deeper. This change occurred when the falls were at the head of Foster's flat, for, from this point up to the upper side of the Eddy basin the river is deep. Spencer's soundings show depths of nearly 100 feet (30 m.) in the stretch between the whirlpool and Foster's flat.

The reef which produces the sharp rapids at the outlet of the whirlpool owes its origin to the breaking away of the east wall of the whirlpool before the vertical fall had time to carve out the sandstone at its base. When the break in the wall came the lowering of the water in the whirlpool must have been quite rapid. Then, continuing their work, the falls cut out the Eddy basin before the volume of the river was reduced. In the lake history, this section is the correlative of the Port Huron stage of Lake Algonquin.

The Gorge of the Whirlpool Rapids.

This section is about three-fourths of a mile long and extends from the upper side of the Eddy basin to the head of the narrows just above the railway bridges. The

average top width is about 750 feet (228 m.); the average width at the water line is about 250 feet (106 m.). Knowing this and the volume of the river and the rate of flow in the rapids, Mr. Gilbert estimated the depth to be 35 or 40 feet (10·7 to 12·2 m.). Spencer's soundings from the upper railway bridge show a midstream depth of 86 feet (26·2 m.) shallowing towards the sides, but the water there is only beginning its descent and has not acquired its full velocity. In the lake history, this section is the correlative of the Nipissing great lakes, and was made, therefore, when the falls carried only the discharge of Lake Erie. Spencer interprets this section in an entirely different way, making it 185 feet (56·4 m.) deep and choked up with fallen blocks to a depth of 100 feet (30·4 m.) or more. The views of Pohlman, Grabau and others are given below in the discussion of the Whirlpool and the St. David buried gorge.

The Upper Great Gorge.

This section, reaching from the head of the narrows just above the railway bridges to the Horseshoe falls, is about two and one-fourth miles (3·8 km.) long. Opposite the American fall it is 1,600 feet (487 m.) wide at the top and is wider than the average from there to the south side of Goat island. Its average width north of the American fall is about 1,350 feet (411 m.), with a least width of 1,025 feet (312 m.) at Swift Drift point. The deepest sounding by the U. S. Lake Survey was in the centre opposite Prospect point, where a depth of 189 feet (57·6m.) was found, and Spencer's deepest sounding, below Goat island near the Horseshoe fall, was 192 feet (58·5 m.). The average central depth north of the American fall is not far from 160 feet (48·8 m.), but there are four soundings in that stretch which show 186 feet (56·7 m.). Above the American fall the central depth is 100 to 120 feet (30·5 to 36·6 m.). This section is the correlative of the present stage of the great lakes, and is still in the making.

The gorge characters and sections and their correlatives in the lake history are summarized in the following table:

CORRELATION OF GORGE SECTIONS WITH LAKE STAGES.

Lake Stages.		Gorge Sections.				
Name.	Relative volume of Falls.	Name of sections.	Length	Division points.	Average top width.	Average depth of river.
1. Early Lake Algonquin.	20 to 25 per cent of present volume. (Whole river nearly equal to present volume.)	First or oldest section. (Lewiston Branch gorge).	2,000 feet (610m)	Mouth of gorge to a point about 2,000 ft. (610 m.) south.	1,400 feet (426 m.), but variable.	140 to 150 feet (42·7 to 45·7 m.)
2. Lake Algonquin, Kirkfield stage.	15 per cent of present volume. (Lake Erie alone).	Old Narrow gorge.	About one mile and one eighth (1·8 km.)	From a point about 2,000 feet (610 m.) south of the gorge mouth to the bend below Niagara University.	1,300 feet (396 m.), very uniform. (Originally narrow. Deepened by rapids; widened by weathering).	60 to 70 feet (18·3 to 21·3 m.)
3. Lake Algonquin, Port Huron stage.	First half slightly greater than present. (4 lakes —). Second half, slightly less than present. (4 lakes —).	Lower Great gorge.	Two miles (3·2 km.)	From the bend below the university to upper side of Eddy basin not including whirlpool. The two halves divide about at the head of Foster rapids.	1st half, 1,600 feet, (487 m.), greatest, 1,825 feet (556·2m.), least, 1,300 feet. 396·2 m.). 2nd half, 1,200 feet (365·7 m.) Least, 1,000 feet (304·2 m.), at lower whirlpool reef. At Eddy basin, 1,200 ft. (365·7 m.)	(1st half) shallow. 35 to 70 feet (10·7 to 21·3 m.). (2nd half) deep. 100 feet or more (30·4 + m.).
4. Nipissing great lakes.	15 per cent of present volume. (Lake Erie alone).	Gorge of whirlpool rapids (New Narrow gorge.)	Three-fourths mile (1·2 km.)	From upper side of Eddy basin to the point of expansion above the railway bridges.	750 feet (228 m.), quite uniform.	35 or 40 to 85 feet. (10·7 or 12·2 to 25·9 m.)

CORRELATION OF GORGE SECTIONS WITH LAKE STAGES.

Lake Stages.		Gorge Sections.				
Name.	Relative volume of Falls.	Name of sections.	Length	Division points.	Average top width.	Average depth of river.
5. Present great lakes	Present volume, 4 lakes.	Upper great gorge.	Two and one-fourth miles (3·6 km.)	From the point of expansion above railway bridges to the Horseshoe fall.	1,350 feet (441·5 m.) Widest opposite American Fall, 1,650 ft. (503 m.); between Prospect Point and Carter Cove, 1,600 feet (487·7 m.). Narrowest at Swift Drift Point, 1,025 feet (311·3 m.).	North of the American Fall, 160 feet. (48·8 m.). (Four of 186 feet (56·7 m.), one of 189 (57·6m.) South of American Fall, 100 to 120 ft. (30·4 to 36·6 m.), one 192 feet (58·5 m.)

The river north of the mouth of the gorge has an average width of about 2,000 feet (610 m.) and an average depth of 45 feet (13·7 m.). The deepest point, 183 feet (55·8 m.) (Spencer), is opposite Queenston. The deepest channel over the bar is about 25 feet (7·6 m.) deep.

The whirlpool is 1,700 feet (518 m.) wide between rock cliffs. The mouth of the old gorge in the embayment south of St. David is one mile (1·6 km.) wide, but contracts to five-eighths of a mile (1·0 km.) at a point one half mile (·8 km.) within the mouth, where the last of the rock cliffs in the embayment are seen.

The accompanying map of Niagara Gorge shows the division points where the gorge is divided into sections and the relation of the sections to each other.

THE WHIRLPOOL AND THE BURIED ST. DAVID GORGE.

It has long been recognized that the rock basin of the whirlpool is older than the rest of the gorge and has had a different history. It is a buried, drift-filled gorge of inter-glacial age. The walls surrounding it on the east and west sides are rock cliffs, like those in the gorge immediately above and below. But on the north and northwest sides the entire wall from the top down to an undetermined depth below the water is composed of sand and gravel, stony clay and boulders, all being loose drift of a later age than the rock gorge itself. Bowman creek descends to the whirlpool from the upland about a mile to the northwest and has cut a deep ravine in the soft sediments, reaching far below the ledges that mark the top of the ancient gorge. The ravine itself lies mainly along the western side, for the western rock wall and cliffs are exposed for some distance. The east side of Bowman ravine however, shows no rock, but is composed entirely of drift, even down where the creek enters the whirlpool. Fragments of the rock cliffs on the two sides of the ancient gorge run a short way north-northwest from the whirlpool showing the direction in which the buried gorge extends.

South of the village of St. David there is a strongly marked re-entrant in the front of the escarpment, the head of which shows no rock for about a mile, but is a

steep and much-gullied slope of drift. This place is in an almost direct line with the prolongation of the older cliff lines at the whirlpool, and it seems impossible to doubt that the gorge extends through to the break in the escarpment south of St. David. One of the faint terminal moraines of this region crosses its northern part and forms the highest part of the filling.

The greatest depth found in the whirlpool by Spencer's soundings is 126 feet (38·4 m.). This is in the middle of the pool and of the upper part of the ancient gorge, where the river in its recent gorge making had only soft drift to remove and no vertical fall with which to bore the rocks at the bottom. This depth belongs, therefore, to the old buried gorge, and, indeed, may not show its full depth in the rock.

Dr. Spencer made a boring into the drift filling of the old gorge at a point about half a mile (·8 km.) northwest of the whirpool, but at a depth of 269 feet (82·m.) encountered difficulties that stopped the work. The boring was started on the general level of the plain and ended at a level of about 24 feet (7·3 m.) above the water in the whirlpool. No rock was encountered, the material being mainly till, sand and some gravel, with boulders at the bottom. While this boring did not reach the rock bottom of the old gorge, it nevertheless strongly confirms the conclusion that the gorge continues to the northwest.

The discovery and re-excavation of the head of the old buried gorge by the modern river appears to have been merely an accident of topography. When the river first began to flow, the lowest line across the plain happened to carry the river over the upper end of the buried gorge, and when the falls had gnawed back to this point they quickly cleaned out the drift materials and resumed rock cutting by a vertical cataract at the southeast side of the whirpool.

Not only is the ancient gorge filled with glacial drift, but at one point in Bowman ravine north of the electric railway embankment, glacial striæ and polishing were found on the west wall of the gorge 90 feet (27·4m) below the top, showing clearly that the gorge was occupied by a current of the ice sheet before it was filled with drift.

Grabau and others who regard the buried gorge as of pre-glacial age point to the widening towards its mouth south of St. David and attribute this to the subaërial

weathering and erosion of the long pre-glacial time. But there is another interpretation. In the first place, the widening is not so great as is stated by Grabau (two miles), but is in fact one mile; and in the second place, the modification which appears to have produced the widening is confined to the west and south side of the mouth of the gorge and appears not to have affected the north side. Supposing the gorge to have been of uniform width when first made, the remnant of the plain on the west side of its mouth would be a salient of the escarpment so situated as to be exposed to the full force of the oncoming ice. On this account it would have been torn away by the last ice sheet and the cliff line would have been driven back and straightened so as to present a more resistant front. The north side of the gorge mouth was not so exposed and would not have been modified in this way.

There are other weighty reasons why this ancient buried gorge should be regarded as inter-glacial rather than pre-glacial. Its top width between the cliffs on the north side of the whirlpool, and also its depth, are so closely identical with the average width and depth of the Upper Great gorge that one cannot resist the impression that it was made by a cataract substantially identical in volume with the present Niagara falls—by an inter-glacial Niagara. So far as the characteristics of the buried gorge are known, it is quite clear that they do not bear out the idea of Pohlman, Grabau and others that it was originally made by a relatively small stream and was widened to its observed width by a long process of subaërial erosion. On the contrary, they seem to show quite clearly that it was made by a vertical cataract of large volume, substantially identical with the present falls.

At the south side of the whirlpool there is a strongly marked reef which produces a sharp separation between the whirlpool and the Eddy basin. This is the upper reef of the whirlpool. When the water is clear the submerged rocks of this reef can be seen for about one quarter of the width out from each shore, and it produces a short but sharply defined rapids. Directly over this reef the top width of the gorge is narrower than over the central part of the Eddy basin. The Eddy basin has not yet been sounded, but the majestic swing of the great return current which sweeps back on its west side shows plainly that the water is deep. The top width and apparent

depth of the Eddy basin are almost identical with the average dimensions of the Upper Great gorge between the railroad bridges and the Park bridge. The reef which shuts it off from the whirlpool, coupled with these characteristics of depth and width, compel the conclusion that the Eddy basin was made by a vertical cataract, like the present falls and with substantially identical volume. The deep hole of the eddy is behind the reef which separates it from the whirlpool, and there is no way to account for it, except by the vertical plunge of a great cataract which somehow suffered a slight interruption that allowed the reef to remain—either such an interruption or something equivalent to it.

It seems impossible to explain the depth of the Eddy basin, its separation from the whirlpool by the upper reef and the sudden shallowing and contraction at the mouth of the gorge of the Whirlpool rapids, on the theory that the buried gorge, the Eddy basin and the gorge of the Whirpool rapids were made by a pre-glacial small stream and afterwards weathered out to their present dimensions. The assembled characters in this part of the gorge seem to show clearly that the St. David gorge was made by an inter-glacial Niagara which suddenly ceased at the south side of the Whirlpool basin. But a much smaller stream probably remained and cut a narrow, shallow gorge reaching 100 to 200 yards (90 to 183 m) south from the whirlpool. When the inter-glacial cataract stopped, the ledge of Lockport limestone which formed the crest of the falls at that time, overhung the south edge of the whirlpool and projected somewhat to the north of the ledges of Whirlpool sandstone which form the present reef. Then after the inter-glacial cataract had ceased, the overhanging ledges fell away and normal cliff recession due to weathering drove the cliff line still farther back, until a relatively stable talus slope was produced. When this condition had been reached a talus slope probably 200 or 300 feet (60 to 90 m.) in width separated the top of the cliff from the reef, that is to say, the top of the cliff, measured on a horizontal plane, was that far south of the reef. Then came the last ice sheet, completely filling the old gorge. When the modern great cataract had gnawed back to the whirlpool and cleared out the filling of drift, it resumed the work of gorge making by a vertical fall at the south side of the whirlpool; not however just where

the inter-glacial cataract had left off, but as much farther back as the cliff line had receded in the meantime—some 200 or 300 feet (60 or 91 m.). This is the equivalent of the interruption of the work of one great cataract mentioned above. The reef is there mainly on account of the weathering that occurred in the time that elapsed between the cessation of the inter-glacial falls and the arrival of the ice sheet which filled and buried the old gorge. And both the inter-glacial and the later cataracts involved in this history had about as large volumes as the present falls. If the alternative of Grabau be adopted nothing is left in the Niagara gorge which can possibly stand as a correlative of the lake stage represented by the Nipissing great lakes, and the absence of this correlative would certainly be much harder to explain than the characters and relations of the reef and the Eddy basin.

ITINERARY.

Toronto to Niagara river.

Niagara Falls is most easily reached from Toronto by crossing Lake Ontario to the mouth of Niagara river 30 miles (48·3 km.) to the southeast and going up the river seven miles (11·3 km.) to Queenston, where electric cars are in waiting for passengers. The voyage lasts about two hours and gives some idea of the smallest of the Great Lakes, which is 180 miles (290 km.) long and from 30 to 50 miles (48 to 80 km.) wide.

Toronto harbour is formed by a hook of sand and gravel extending westward for two and a half miles (4.0 km.) from the mouth of Don river, and then bending north toward the main shore. The bar, which is called Toronto island, is built of materials transported by the easterly storms from Scarboro heights. Two artificial channels give egress to the lake.

From the stern of the steamer there is a view of Toronto and also of Scarboro heights, ten miles (16 km.) east of the harbour, including the highest point on the actual shore of Lake Ontario, rising 355 feet (108 m.) above the water as pale cliffs of clay.

Before Scarboro heights fade from view the Niagara escarpment may be seen from the bow of the ship. It is

7 miles (11·3 km.) from the south shore of the lake but rises in places 380 feet (115·8 m.) above it, or 625 feet (190·5 m.) above the sea, the elevation of Lake Ontario being 245 or 246 feet (74·7 or 75·0 m.).

The basin of Lake Ontario is not symmetrical, since the deepest soundings occur near the south shore, where depths of 400 or 500 feet (121·9 or 152·4 m.) are frequently found. The greatest depth recorded is 738 feet (224·9 m.), so that the bottom goes 492 feet (151 m.) below sea level. The basin was probably once a river valley, its northeastern end at the Thousand islands having been warped up at the close of the Ice age.

Lake Ontario to Niagara Falls.

The Lower Niagara River—Approaching the mouth of Niagara river, the steamer crosses what is supposed to be a submerged delta of Niagara river called Niagara bar. Its front descends to a depth of over 200 feet (60·9 m.) quite steeply. The depth of the water on it varies from less than 15 feet (4·6 m.) to about 40 feet (12·2 m.). Many soundings in the shallower part show "rocky" bottom, so it is not certain that it is all a delta deposit.

The banks of Niagara river below the gorge are steep and rise from a height of 20 to 30 feet (6 to 9 m.) near the lake to 125 feet (38·2 m.) at Lewiston. The average width is about 2000 feet (610 m.). The banks are red shale with thin drift on top, but two miles (3·2 km.) south of Niagara-on-the-lake the rock disappears and the banks on both sides are wholly of drift for about a mile. This is probably an old river channel of inter-glacial or pre-glacial age and has been regarded by some as a possible continuation of the buried St David gorge. A sharply cut terrace 20 to 25 feet (6·1 to 7·6 m.) above the river at the Stella Niagara school, two miles north of Lewiston, is an abandoned portion of the old bed where the river flowed at a higher level than now. It is floored with coarse gravel and cobbles, which show in the bank. Just opposite, on the Canadian side, there is another fragment of old channel at a slightly higher level. This is three-fourths of a mile (1·2 km.) long, relatively narrow and the outer part of its course is about one-third (·5 km.) of a mile from the river.

Lewiston to Niagara Falls—At the landing at Lewiston there is a good view of the front of the escarpment and the mouth of Niagara gorge.

The railway between Lewiston and Niagara ascends by a loop to the top of the sandstone terrace, passes through a short tunnel and enters the mouth of the gorge more than 140 feet (43 m.) above the water. For about two miles (3·2 km.) the railway runs along the steep face of the gorge wall, cutting the strata obliquely as it ascends. As the rocks dip gently toward the south, and the railroad ascends in the same direction, it cuts all the strata from the Whirlpool sandstone up to the Lockport (Niagara) limestone exposing good sections for examination and for the collection of fossils.

Below Niagara university the railway turns away from the river through a deep cut in the Lockport limestone and soon reaches the level of the plain in which the Niagara gorge is made. After passing Suspension bridge, the train runs for nearly a mile along the brink of the Upper Great gorge and some fine views are obtained of this part of the river, including the falls about two miles (3 km.) away. For a few moments there is a fine view backward from the right side of the train, into the head of the narrow gorge of Whirlpool rapids.

Niagara Falls and the Rapids from the American Side.

Old River Terraces.—Entering Prospect park at the Soldiers monument, the level of the ground is seen to descend by two rather ill-defined steps or terraces. These terraces are composed mainly of gravel and mark old levels of Niagara river when the falls were located probably one and a half miles (2·4 km.) or more below their present site.

Prospect Point.—One of the finest views on the American side is to be obtained from this point. It is at the northern end of the American fall, where the water passes smoothly over the brink. The American fall is seen lengthwise along its crest, the observer's feet being but little above the level of the water. Viewed in this way the protruding and re-entrant angles of the crest seem relatively much greater than they really are, for the crest line is nearly straight. The water sheet passing over this fall is much thinner than that of the Horse-

shoe fall, being not over three feet (·9 m.) deep in the deepest part and over much of the central part one foot (·3 m.) or less. This fall is about 168 feet (51·2 m.) high, but is about two feet (·6 m.) higher at its south edge than at its north. The water does not plunge directly into the great caldron or pool below, but falls upon a mass of great blocks which have fallen from above. Some of these are of huge size. One known as the Rock of Ages lies below the southern end of the fall.

The American Fall from Prospect point, looking south. The Horseshoe Fall in the distance.

These blocks are fragments of the Lockport (Niagara) limestone from the cliff over which the American fall now passes ; and they rest mainly on a bench of Clinton limestone which projects about 300 feet (90 m.) out from the foot of the fall. The edge of this shelf is in line with the edge of the same shelf both north and south of the American fall, but except under the fall it is covered with a heavy mass of talus. Under the fall the material has all been carried away and only the great blocks remain. Elsewhere the talus contains much fine material which largely conceals the blocks.

A few paces north of Prospect point is Hennepin's View, supposed to mark the spot from which the first white man beheld the falls. The point is higher and affords a better general view.

Slow Recession of American Fall.—The crest of the American fall is about 1,000 feet (305 m.) long and forms a nearly straight line continuous with the cliff on either side, so that that part of the cliff which forms the brink of the fall has receded little if any more than the adjacent parts which have not been the crest of a waterfall. Gilbert, Spencer and others have made estimates of the rate of recession of the American fall based on Hall's and later surveys. Spencer found the rate to be about ·6 feet (·18 m.) per year, but Gilbert found a very large error in Hall's map. The northern part of Hall's crest line is represented as a large salient projecting about 100 feet (30·4 m.) too far. After making this correction from contemporary drawings, Gilbert concluded the rate "is probably as small as ·2 (·06 m.) of a foot per annum." But it may be much less than this, as the following considerations show. The talus slopes north and south of the American fall are no wider than that directly in front of it, except for an interval of 300 or 400 feet (90 or 122 m.) in the central part, where the width is a very little greater. Manifestly, if normal cliff recession due to weathering has produced talus slopes as wide as that in front of the American fall, the production of a slope of the same width along the front of the falls need not be attributed to the work of the falls, but is quite as likely to be due to normal cliff recession.

The sheet of water passing over this fall is thin and feeble and has not been able to remove or wear the blocks away, even in the 400 or 500 years that have probably elapsed since the Horseshoe fall was finally separated from the American fall. If the slight re-entrant in the central part of the crest line was made by the fall as distinguished from cliff recession by weathering, and was deepened even as much as 50 feet (15·2 m.), the average rate would be about ·1 of a foot (·03 m.), or a little more than one inch (2·5 cm.) a year. On the rest of the crest line there is no certain evidence of recession by the action of the falls.

Goat Island.—This island separates the American fall and rapids from the Horseshoe fall and the rapids above it. The surface is nearly flat, and composed of

gravel, much of it coarse. Towards its west end the gravel is 10 to 12 feet (3·0 to 3·6 m.) deep and overlies 25 or 30 (7·6 or 9·1 m.) feet of stony till or boulder clay, which in turn rests upon the Lockport limestone.

From Stedman bluff one looks down upon the American fall and the rapids above it and into the mist and spray which largely conceal from sight the great blocks below. In the distance to the north one looks down the upper gorge to the railroad bridges. The turbulent water, with its wonderful foam pattern, its whirls and boils, is a fascinating object to study. The currents show how small is the influence of the water passing over the American fall compared with that

The American Fall, looking north from bluff at northwest corner of Goat Island; Luna Island in the foreground.

which comes from the greater cataract. From this point one sees in the foreground the relatively small but beautiful Luna fall, with Luna island on its north side, beyond which a good view is had of the central part of the American fall, where the re-entrant angle is deepest and where recession, if any, has been greatest. The thinness of the water sheet here is quite notable as compared with the heavier mass beyond.

The luxuriance of the verdure of Luna island, like that on the other islands and the main land wherever within reach of the spray, is notable. In winter the spray forms great domes of ice reaching more than half-way up to the top of the falls. They do not obstruct the falling water, but rest upon the great blocks and the Clinton ledge just in front. Often the ice domes do not wholly disappear until June or July.

From Goat island, those who wish may make the excursion into the Cave of the Winds. From the foot of the stairs the passage leads behind Luna fall to a point below Luna island, returning through the spray in front of Luna fall. Formerly, visitors went behind the north end of the American fall, and it was there that Mark Twain said the he felt as though he had the Atlantic ocean going down his back.

Fossil Shells (**Pleistocene**).—When the great cataract was situated a mile or two below its present place, Goat island formed a part of the gravelly floor of the river, which at that time flowed over the site of Goat island with a relatively gentle current, probably such a current as now characterizes the river a few miles below Buffalo. The gravelly bottom of the river on Goat island was then a favorite habitat for certain forms of mollusks. Fossil shells occur in great abundance in a gravel pit in the woods near the western end of Goat island.

In his guide book of 1901, Grabau includes a list of Pleistocene fossils of the Niagara region compiled by Miss Elizabeth J. Letson, of Buffalo. A total of 31 species are given from seven localities. A greater number of species were found on Goat island than at any other place, the number being 28. The localities given are Goat island, Prospect park, Queen Victoria park, Muddy creek, Whirlpool (American side), Whirlpool (Canadian side), and Foster's flats. The species given are as follows:—

Gastropoda.

1 Pleurocera subulare Lea
2 Goniobasis livescens (Menke)
3 G. livescens niagarensis (Lea)
4 G. haldemani Tryon
5 Amnicola limosa (Say)
6 A. letsoni Walker
7 Bythinella obtusa (Lea)
8 Pomatiopsis lapidaria (Say)
9 Valvata tricarinata Say
10 V. sincera Say
11 Campeloma decisa Say
12 Limnæa columella Say
13 L. desidiosa Say
14 L. batascopium Say
15 Physa heterostropa Say
16 Planorbis bicarinatus Say

Pelecypoda.

17 P. parvus Say
18 Sphærium striatinum (Lam.)
19 S. stamineum (Conrad)
20 Pisidium virginicum Bourg
21 P. compressum Prime
22 P. abditum Haldeman
23 P. ultra-montanum Prime
24 P. scutellatum Sterki
25 Lampsilis rectus (Lam.)
26 L. ellipsiformis (Conrad)
27 Alasmidonta calceola (Lea)
28 A. truncata (Wright)
29 Unio gibbosus Barnes
30 Quadrula solida (Lea)
31 Q. coccinda (Conrad)

A gravel bank in Queen Victoria park about opposite the middle of the rapids was accessible before the power instalments and the park improvements and was very rich in fossil shells. Professor Coleman collected fossils at this locality and reports the following species:

Gastropoda.	*Pelecypoda.*
Pleurocera subulare Lea	Sphærium solidulum
Goniobasis livescens Menke	S. Striatinum Lam.
Physa heterostropha Say	Unio gibbosus Barnes
Limnæa decidiosa Say	U. luteolus
	U. rectus
	U. clavus
	U. occidens
	Quadrula solida Lea
	Q. coccinea Conrad

The Horseshoe Fall from Porter Bluff and Terrapin Rocks.

From the top of the bluff at the southwestern corner of Goat Island there is a fine view of the western part of the Horseshoe fall, of the nearer part of the rapids above the fall and of the bluffs back from the river on the west side. The water here and for a considerable distance farther out is very shallow; much of the rock is exposed and the surface is dotted here and there with stranded blocks of limestone. The shallows near the island is called Goat Island shelf. A little above the water level, the ledge of the Clinton limestone projects out about 500 feet 150 m.) from the extreme end of Goat island and is covered with the same assemblage of huge fallen blocks as at the American fall. The fine material has been washed away leaving blocks that are on the average considerably larger than those below the American fall.

The view from the Terrapin rocks northward along the western face of Goat island shows very clearly the relation of the American fall to the cliff line, for beyond Goat island and extending substantially in the same line, the front of the American fall is in plain view and also a part of the cliff farther north. The whole front is a nearly straight line which the American fall appears not to have modified perceptibly.

The central part of Horseshoe fall and especially the head or apex of the curved brink are seen here at too low an angle for a clear appreciation of their outline. The deep emerald green water pours over the brink in a graceful unbroken curve. The water there is supposed to reach

20 to 25 feet (6·1 to 7·6 m.) in depth. Twenty years or more ago the angle at the apex of the fall was sharper and more acute. The principal change in the outline in recent years has been a falling away of the crest along the line to the right of the apex as seen from this point.

The water pouring into the angle near the apex sometimes produces a remarkable effect, like an explosion in the depths below. It makes a perceptible booming sound and throws up jets of spray to heights considerably above the top of the falls. This effect is best seen from here and was formerly more marked than now.

The Horseshoe Fall, looking south from bluff at southwest corner of Goat Island. Goat island shelf in the foreground.

The Sister Islands and the First Cascade.—Here is a picturesque spot where small branches of the rapids pass between small rocky islands. The beds of Lockport limestone here are thick and massive, leaving an abrupt descent of five or six feet where they part along their joint planes. One of these beds runs from the shore of Goat island just above the Sister islands directly south across the river. It extends in a nearly straight line and the water falls over it in what is known as the First cascade.

The loosened blocks are gradually pushed away, probably to some extent by the water, but more effectively by the heavy ice cakes in the spring. The Sister islands are remnants of this massive bed.

From the park on the American side one may descend by an elevator to the foot of the American fall, where an impressive idea of the majesty of the falls may be obtained by climbing the path and approaching close to the falling water. A drenching spray is likely to be found at this spot and oilskins may be necessary.

The trip on the Maid of the Mist.

The Maid of the Mist provides one of the most impressive scenic boat rides in the world. This steamer proceeds southward from the landing, passing in front of the American fall 150 or 200 yards (130 or 180 m.) out from the line of rocks at its base. The great height of the fall and the majestic descent of the water is here seen to the best advantage. As the smooth water quietly curves over the brink it glistens in the sunshine to contribute a moment later to the deep roar and the great cloud of spray and mist at the bottom. The spray and mist obscure the view of the lower part of the falling water and sometimes also the rocks along the shore. Along the central and southern part of the falls where the water sheet is thin, a better view is obtained. The cliff along the west side of Goat island is precipitous or overhanging in its upper part, where the face is composed of limestone, but there is a heavy talus with many large blocks along its base. Towards its top one sees a distinct change of angle where the drift and gravel of Goat island rest upon the rock, for these softer sediments make a slope which is steep but not vertical. The steamer passes quite near the great blocks below Goat Island shelf, and then, passing out of the more quiet waters, enters the foamy, turbulent pool below the Horseshoe falls. The deepest sounding in the river (192 feet; 58·5 m.) was found just off the rocks below Goat Island shelf, by Spencer. The steamer approaches through a turmoil of foaming water and spray surprisingly near to the base of the great fall. But a powerful current flows outward from the cataract and into this the steamer turns and is carried swiftly down stream. It is said that the white, frothy water is so surcharged with

air that the steamer settles several inches deeper in it than she does in the clear waters farther down. After turning away and floating down the stream a few hundred yards, as though baffled in her attempt to enter the roaring portal, the steamer usually turns back again towards Goat island and makes a second advance into the spray and foam. After the second approach she steams rapidly down the centre of the river keeping well out from the west shore where there are some dangerous rocks opposite the American fall. Before reaching the graceful arch of the Park bridge, she swings around to the west and lands on the Canadian side at a bench or terrace of upper Medina sandstone which rises but little above the water. When the main fall was passing the front of the American fall the crest line was unusually wide, with a consequent thinning of the water sheet. The soundings in this part of the gorge show the deepest part of the channel to be nearer the eastern side, indicating that the heaviest water fell along that line. Toward the west side in Carter cove and south of it the water must have been shallower and lacked power to remove the harder thin layers which now form the bench at that place.

Trip to Falls View.

In many respects the grandest and certainly the most comprehensive view of the falls and of the river, both above and below the falls, is obtained from a point called Falls View on the Canadian side on the edge of the high bluff near the Loretto convent. To reach this spot by the easiest route, the visitor crosses the park bridge and walks up the ferry road from the Clifton hotel to the street railway just opposite Victoria Park station. The westbound car goes out Lundy lane to the Stamford road, which runs south and southeast along the top of the Niagara Falls moraine. A few steps from the corner is the monument on the battlefield of Lundy Lane (July 25, 1814). On the Stamford road the car follows at first a little east of the crest and farther on a little west of it and for half a mile or more the crest of the ridge has the Lundy or Dana beach resting on it as a summit gravel bar. At Falls View one looks down upon the whole scene of the river and rapids above the falls and into the caldron and canyon below. From this point one can make an interest-

ing study of the currents in the rapids above the falls. The three cascades with Sister island and Goat island are directly in front and the course followed by the deeper currents as they approach the brink of the falls may easily be followed. The stony shallows in the lower central part of the rapids are clearly seen. From here one sees also a distant side view of the American fall and may note quite clearly the nearly straight line of the cliff of Goat island, the American fall and the cliff beyond Prospect point. The grand sweep of the bluff forming the embayment between Table Rock house and Dufferin islands is well seen from this point, and also the great depth of the drift. About 100 yards (90 m.) north of Falls View the crest of the Niagara Falls moraine comes out to the edge of the bluff above the Michigan Central railway, and is there abruptly cut off. One sees clearly that its normal continuation would carry it far over the embayment, probably over the edge of the rapids. From the top of the moraine to the bottom of the river at the deepest sounding below Horseshoe fall is nearly 500 feet (150 m.). One may return on the car, or, taking a stairway to the Michigan Central Falls View stopping place, may descend the steep bluff by a rough path to the flats in the park below and thence by a short walk to the parapet at the edge of Horseshoe fall and to the Table Rock house.

The Falls and the Gorge from the Canadian Side.

Views from the Park bridge and the West Cliff—From the Park bridge one gets the best views of the Upper Great gorge, giving a good impression of its dimensions. In order to form a true conception of its depth, however, it is necessary to remember that the average depth of water along its axis of greatest depth is 150 to 160 feet (46 to 50 m.), with a number of soundings showing places 30 to 40 feet (9 to 12 m.) deeper. If the water were taken away the beholder would be looking down into a canyon 350 to 400 feet deep (106 to 120 m.).

The well defined embayment in the cliff line, near the entrance gate to Queen Victoria park, seen by following the trolley line south along the Canadian side, is the curve around the top of Carter cove. A little farther on the foam pattern and swirling of the water shows the presence of a large rock or reef close to the surface of the water. This

rock is 300 or 400 feet (90 or 120 m.) out from the shore and apparently rests upon, or is a part of, the submerged terrace which extends southward along the west side. The view of the American fall is finest from this point, being directly in front, and shows the thinness of its water sheet and the mass of blocks along its base. The cliff along the west side of Goat island is also in full view, with the Horseshoe fall in the distance on the right. From this point, or better from one of the little pavilions 100 yards or so farther on, one obtains the best view of the two cataracts at one sweep.

The American Fall from a point directly opposite on the Canadian side.

Horseshoe Fall from the Parapet.—The view from the parapet at Table Rock house affords the climax of the nearer views of Horseshoe fall, which is much the greater and more powerful of the two cataracts. One looks eastward along the curving crest line of the fall toward the angle at the apex 1,000 feet (300 m.) or more away. In the foreground the water is not deep, but beyond this the emerald green of the heavy, unbroken mass of clear water as it bends smoothly and gracefully over the brink, is a most impressive spectacle. One cannot see far down the face of the falling water, on account of the immense volume of spray which obstructs the view, and

the surface of the water below the falls is dimly visible only at a considerable distance out from the foot of the cataract On account of its frothy whiteness, it is somewhat difficult to judge of its distance below the observer. From the angle of the parapet it can usually be seen directly below or a little to the left. The view at the parapet varies much with the wind and the drift of the spray cloud. Sometimes one can see far along the crest into the distant angle; while at other times, especially when the wind blows from the southeast, the whole parapet is enveloped in a drenching mist. In the middle or late afternoon in clear weather a magnificent rainbow is seen in the spray.

Western part of Horseshoe Fall from the parapet near Table Rock house; looking southeast.

The greatest amount of recession in recent years has taken place in that part of the falls where the heaviest water is seen passing over, but for about 20 years there has been no perceptible recession where the apex of the falls was so prominent some years ago.

From the top of the Table Rock house a splendid view is obtained toward the centre of the falls. If mist does not obstruct the view of the apex, an interesting

detail may be seen at that point. Instead of finding a sheer descent from the brink, the heavy water at the apex strikes a rock shelf, estimated to be about 40 feet (12 m.) below the top, from which it rebounds whitened and foamy before making the final plunge. The shelf must be of large proportions and has existed for many years. Before the recent improvements for power development in Queen Victoria park, a thin water sheet like that which flows over the Goat Island shelf fell over the cliff where the parapet now stands and the edge of the water on the brink was then 415 feet (126·5 m.) nearer Table Rock house than it is now. The total length of the crest line was then about 2,950 feet (900 m.).

For a nominal fee visitors may descend by an elevator to a tunnel leading to a point under the nearer part of the falls, about at the edge of the heavy water, where a window-like opening looking out towards the falling water has been made. Nothing can be seen except a diffused varying light that comes through the water. The thunderous roar of the water is deafening. The trip is worth making for the impression of titanic power which this sound produces and for the realization of one's nearness to the great cataract.

The Recession of Horseshoe Fall.—When it is understood that the gorge extending for nearly seven miles (11·3 km.) from the escarpment at Lewiston up to the Horseshoe fall, was made by the Niagara river itself since the disappearance of the last ice sheet, it becomes a matter of much interest to know at what rate or rates the gorge was lengthened and how long a time has been involved. Those who have studied this problem carefully have reached different results, that varied chiefly according to the authors' conceptions of the history of the Niagara river and of the dependence of that history upon the Great Lakes history. Many other variable factors enter in but no other approaches in importance to the relation of Niagara to the great lakes. If the gorge were exactly seven miles (11·3 km.) long and the rate of recession of the cataract had averaged exactly five feet (1·5 m.) per annum, it would be easy to say that it has been 7,392 years since the falls began at Queenston. Those who have held strongly to the conclusion that the duration of Niagara has been no more than 7,000 to 10,000 years seem to have relied upon a simple calculation of this kind.

But the problem is extremely complicated and involves many elements that are incapable of exact determination. Many assumptions have to be made and the value of the results depend upon their accuracy.

Five instrumental surveys were made between 1842 and 1905, with the object of determining the precise configuration of the crest lines of the two cataracts. The first was begun by E. L. Blackwell under the direction of James Hall, in 1841 and finished in the autumn of 1842. A series of monuments were established by this survey for the use of future investigators. The second survey was made by the U. S. Lake Survey in 1875 under the direction of Major C. B. Comstock, the field work being done by F. M. Towar; the third in 1886 for the U. S. Geological Survey by R. S. Woodward; the fourth in 1890 by A. S. Kibbe under the direction of John Bogart, State Engineer of New York, and the fifth by the U. S. Geological Survey and the State Engineer of New York, the field work being done by W. Carvel Hall in 1905. A survey was also made in 1906 by J. W. Spencer and one or two others have been made more recently.

Based on the five surveys mentioned, Mr. G. K. Gilbert made a careful study of the rate of recession of the falls in a report published in 1907. He concluded that between 1842 and 1905 the main cataract had receded at an average rate of about 5 feet (1·5 m.) per annum. In reaching this value for the rate of recession Mr.Gilbert's calculations tended to a result near 4·5 feet (1·37 m.) per annum, but as he states, he chose the nearest whole number as being, in all probability, as near the truth as a small fraction under that number, since precise results are not to be obtained with such data as are available for this kind of a calculation. By this rate the time taken by the cataract in making the Upper Great gorge would be 2,400 or 2,500 years. He has not given an estimate of the total duration of the falls, but some years ago expressed himself as favouring a long time rather than a short one.

From his exhaustive studies on the rate of recession, J. W. Spencer finds the rate of recession of Horsehoe fall to be 4·2 feet (1·28 m.) per annum, and at the Erie stage ·42 (·128 m.) of a foot per annum. Dr. Spencer made careful allowances for many modifying factors in making his calculations for the total duration of the falls, but

did not interpret the great lakes history as it is now accepted. In 1894 Spencer found the total duration of Niagara falls to have been 32,200 years. Later studies (1906-7) led him to change this result to 39,000 years.

In a paper published in 1898, the writer of this text ventured the opinion that the total duration of the falls was probably 50,000 years or more. It seems clear now, however, that this estimate was based on too slow a rate for those sections of the gorge which were made by the cataract with small volume. A review of the data bearing upon the rate of recession of Horseshoe fall has led to the conclusion that the average rate of recession in the Upper Great gorge has been very nearly 4.5 feet (1·37 m.) per annum. This applies to the Upper Great gorge and with slight modification to the Lower Great gorge, but it does not apply to either the New or the Old Narrow gorges, nor to the first or oldest section near Queenston.

At the very outset an assumption has to be made which involves the decision of a difficult question. What part of the crest line or what point upon it shall be taken to represent the rate of recession? In the long run the recession of the apex or extreme re-entrant of the crest line will yield the true rate, but in a relatively short period, like that of the instrumental surveys (1842-1905) this method may prove quite unsatisfactory, as indeed, it has done. In a period preceding 1890 the apex retreated at a relatively rapid rate and became very acute on a line turning to one side from the main axis of the gorge. Then the apex became nearly stationary and has remained so for more than 20 years. There was not a deep enough and large enough caldron beneath the acute angle to undermine the capping hard layers. But while recession ceased at the apex, it continued on a different line passing west of the apex and more nearly on the main axis of the gorge produced from the north. Thus, the former apex will soon cease to be the apex, a new one being established farther west. It seems better to take a certain limited central portion where deep water is passing over, say a width of 400 or 500 feet (120 or 150 m.) and use the measured mean rate of recession there for the rate of elongation of the gorge. This is the method used by Mr. Gilbert.

Again, in a broader sense the recession of the falls tends to be rythmical, not exactly periodical, but recurrent with alternating phases in which the crest line

becomes more acute and then less acute in its general form. When acuteness is increasing, the rate is a little more rapid than the mean; when it is decreasing it is a little slower than the mean.

Wherever the rock floor above the falls was unusually flat and wide and without local depressions or small valleys to cause concentration of water in greater depth at some particular place, the water sheet on the crest became relatively thin, the falls widened and the gorge was made wider and proportionally shallower. At such times the rate of recession must have been considerably slower, for the undermining power of the falls was reduced. Such a period affected the falls, while the main cataract was passing in front of the American fall, and Goat island, where the gorge is wider than the average and shallower. The rate here in the widest part was probably reduced one-half.

The slower rate in the wider, shallower part opposite the American fall and Goat island somewhat reduces the average rate for the whole section making it slightly less than Mr. Gilbert's five feet (1·5 m.) a year and indicating a period of 2,700 to 3,000 years for the making of the Upper Great gorge.

But the most uncertain element in attempting to determine the whole duration of the falls is the rate in the two Erie sections, the Old Narrow gorge and the gorge of the Whirlpool rapids; and the oldest section near Queenston. Spencer makes the rate of recession with Lake Erie waters alone ·42 of a foot (·128 m.) a year, the volume then being only 15 per cent of the present volume. But, with a volume so much smaller, the rate may be greatly modified by local conditions, especially by those which affect the depth of the water on the crest of the fall. This is clearly shown by the history of the American fall, which has less than five per cent of the whole volume of the river or less than one-third of the discharge of Lake Erie.

The American fall is a remarkable instance of lack of concentration of water depth on the crest line. The crest is 1,000 feet (304 m.) long and the water on it is not over three feet (·9 m.) deep, while much of it is one foot or less. If the crest was, say, 100 feet (30·5 m.) long the water would be 18 or 20 feet (5·5 or 6 m.) deep

and a fall of this description would be an active gorge-making agent, whereas the American fall in its present state hardly bears that distinction.

A cataract of three times the volume of the American fall, such as were the falls in the two Erie sections, would be more powerful, but, other conditions being the same, the rate of its recession in gorge making would be conditioned in the same way, according as the water on its crest was concentrated or attenuated beyond the average. For an average depth of between 5 and 10 feet (1·5 and 3 m.) on the crest, which would signify neither extreme concentration, nor extreme attenuation, and where the capping limestone was thin or of moderate thickness, Spencer's rate of ·42 of a foot (·128 m.) per year seems a little slow. But where the capping limestone had great thickness it is probably too rapid. It seems certain that the cataracts in both of the Erie gorges probably underwent considerable variations of this kind. Indeed, on account of the number and magnitudes of the variable and uncertain elements affecting the rate of recession, especially in the older parts of the gorge, it does not seem possible to state in precise terms the total duration of the falls. It appears to have been somewhere between 20,000 and 30,000 years, possibly even 35,000 years. It is believed that an attempt to set the estimate between narrower limits would add nothing to its value.

The Rapids above the Falls.—From Table Rock house the car runs southward along the shore of the rapids, affording a good view at several places of the powerful current as it rushes swiftly towards the falls. It is easily seen that a deep current flows close along the shore, while farther out there are many rocks projecting above the water. Sixty or seventy years ago there was a low island covered with bushes and small trees in that part of the rapids. There is considerable area lying south and southeast from the apex over which the water is now shallow. A deep, strong current passes north of the shallows and falls over the brink at and north of the apex of the fall and another larger current passes south and west of it and falls over the brink west of the apex. If this arrangement of the deeper currents continues for sufficient length of time an island will appear between them, as Goat island is now between the divided parts of the river. It seems certain also that by the time the

falls have cut back half a mile farther the American fall will run dry. These would appear to be natural tendencies of development, but the interference of man may modify them.

The Dufferin Islands.—This group of small, low islands forms part of the abandoned floor of a relatively small embayment cut sharply into the deep drift sheet which forms the southern bank of the river at this point. The islands and the embayment in which they lie are of relatively recent origin. The islands were four in number and were divided by channels 50 to 100 feet (15 to 30 m.) wide through which streams one to four or five feet (1 to 1·5 m.) deep rushed with rapid currents, but recently, dams have been constructed with gates controlling the volume of the two streams and another dam at the outlet produces a large pond in the bend of the main stream south and west of the islands.

The embayment appears to be related to the rock ledges which formed the First and Second cascades at the head of the rapids. The bed rock dips gently toward the south, so that its surface is lower at Dufferin islands than at Sister islands on the north side. On this account the line of deepest water and the strongest current has had a tendency to hug the Canadian shore. In consequence the river has been and is still cutting its bank on the Canadian side. The Dufferin channel starts in just above the First cascade and re-enters the river below the Second cascade. This gives it a rapid descent and high cutting power. The high, steep bluff which borders the embayment shows how effective that cutting was. The surface of the islands is composed mainly of gravel, showing that they formed the floor of the embayment as the cutting progressed.

Chippawa Creek and the River above the Rapids.—It is worth while to make the short trip on the car from the head of the rapids to the village of Chippawa, in order to get a view of the wide, placid river above the rapids. Here the river is seen flowing quietly in a wide shallow bed between banks of drift. At Chippawa the river is a mile wide and its greatest measured depth is 22 feet (6·7 m.), about 1,000 feet (300 m.) from the south shore. For several miles above the rapids the river bank on the Canadian side is a freshly cut bluff of till, while on the New York side the bank is an old, low bluff

of till now being abandoned and has wide, reedy shallows all along its base.

The old Drift Banks of Niagara River.—When the falls first began at the escarpment south of Queenston, there was no gorge and the river flowed across the country on the line of lowest level. Although it had no bed at first, it very soon made one for itself in the drift. In consequence of its greater width, fragments of the old drift banks are found at intervals nearly to the mouth of the gorge. Anyone who would doubt the making of the rock gorge by the present post-glacial river will have to explain how the old river banks in the drift could have originated, for evidently the river could have flowed in its old drift bed at any given place only before the gorge had been cut back to that place.

The most remarkable parts are the three embayments on the west side near the falls. The earliest embayment extends southward from a point about 1,000 feet (300 m.) south of Hubbard point nearly to Table Rock house. This appears to have been cut partly during the earlier history of the river, when the falls were somewhere north of Hubbard point, and partly, especially the southern part, while the falls were receding down the southward slope of the old valley mentioned below. This part extends from a point one-fourth of a mile (·4 km.) north of the park bridge to the western end of Goat island. The large embayment south of Table Rock house had not then been made and the western bluff of that time probably extended south and southeast from near Table Rock house out over the present site of the Horseshoe falls and the rapids above, in all probability along a line several hundred feet out from the shore.

At this time the river began to cut the bank at a new place on the west side, where the rapids are now, and soon formed the strongly marked embayment which curves around west of the present rapids. The cutting of this embayment was apparently due to the momentum of the water as it descended the sloping rock floor of the rapids toward the west. The rushing water was turned to the east, but not until it had cut heavily into the drift, and before the process ceased it had carved out the great embayment now seen. This work was probably completed in a rela-

tively brief time and that part of its floor which is now dry ground had probably not been long abandoned by the rapids when Father Hennepin saw the falls in 1678, for there was still a crossfall on the west side, which as Spencer has pointed out, was produced by water following a channel nearer the base of the bluff by several hundred feet than the edge of the present rapids.

The smaller but deeper embayment at Dufferin island was made at a still later time.

The Falls-Chippawa Buried Valley.—The rock floor of the rapids above both cataracts is the eastern slope of what Spencer named the Falls-Chippawa buried valley. This is an old valley in the pre-glacial rock surface and except where excavated by Niagara river is completely buried and obliterated by the drift. Its head appears to have been about at Hubbard point, the valley descending gently and widening toward the south and southwest. According to Spencer, the rock floor of this old valley has determined the height of the falls since they passed Hubbard point and the crest line of the Horseshoe fall is now 50 or 60 feet (15 to 18 m.) lower than formerly. It is the westward sloping side of this old valley which makes the rapids above the falls and it was the same circumstance that caused the two larger embayments in the drift.

The drift composing the deep filling of the old valley at the falls contains a variety of deposits, including a bed of old or pre-Wisconsin till at the bottom. Near Horseshoe fall this is followed by a bed of quicksand above which there is a heavy bed of ground moraine. Excepting occasional thin deposits of sand or gravel or lake clay, the ground moraine is ordinarily the upper deposit of this region. But the top of the bluff west of Horseshoe falls and southward is a terminal moraine, called the Niagara Falls moraine and made by the Lake Ontario lobe of the last ice sheet as it finally withdrew from this region.

The Upper Great Gorge.—The Gorge railway runs from Horseshoe falls to Queenston, returning on the American side. On the Canadian side it follows the cliffs at the top of the gorge to its mouth at Queenston, affording many fine views into the great chasm. On this trip the gorge sections are seen in the reverse order from

that in which they were made. The gorge characters and sections have been described above and condensed in a tabulated statement. It is not necessary therefore to repeat here the measurements and statements given there. Attention is directed particularly to those points in the gorge which have a critical bearing upon its history and which stand in definite correlation with the lake history.

The first two and a quarter miles (3·6 km.), from

The Upper Great gorge, looking south from the east end of the cantilever railway bridge. The Park bridge and the Falls are seen in the distance, two miles away. Note the relatively placid water of the great pool and the ripple in the foreground where the water is drawing with increasing velocity into the head of the Gorge of the Whirlpool rapids.

Horseshoe fall to the railway bridges, lie along the cliff of the Upper Great gorge. Noticing particularly the great width of this section and the quietness and apparent great depth of the water, one is prepared to appreciate more fully the contrast in the dimensions of the next section. Soon after passing the west end of the Park bridge the car ascends 40 to 50 feet (12 or 15 m.) to the top of Johnson ridge hear Hubbard point. This ridge is of Lockport limestone and forms the highest rock barrier in the line of the

gorge. Two or three sharp embayments occur here, one north and another south of Hubbard point and a smaller one on the east side. There was probably a small and relatively narrow pre-glacial valley or trench at this place which formed the col between the head of Spencer's Falls-Chippawa buried valley and a smaller valley descending gently northward to the whirlpool. This narrow little valley may have had windings which guided the falls in such a way as to produce the embayments now seen.

The Whirlpool rapids and narrow, shallow gorge, looking south (up stream) from near Whirlpool point; the railway bridges in the distance. This view looks into the mouth of the narrow gorge. The wider part in the foreground is a part of the Eddy basin. The widening to the right beyond the edge of the picture is more pronounced than that shown in the middle foreground.

This section of the gorge also shows to best advantage the slight alternate contractions and expansions which seem to record a rythmical tendency in the recession of the falls.

Gorge of the Whirlpool Rapids.—At the cantilever railway bridge one sees the head of the Whirlpool rapids. The sudden sharp contraction of the top width of the gorge is well shown at this point, the narrow section to the north

having only a little more than half the average width of the section above. From the quiet pool above, the water moves with increasing speed as it enters the narrows. For 100 yards or so it retains its glassy smoothness, but by the time it passes the second railway bridge it breaks into the tremendous billows of Whirlpool rapids. The old drift banks of the river are well displayed in this section. They are 10 to 25 feet (3 to 8 m.) high and stand 300 to 500 feet (100 to 150 m.) back from the cliff line on either side. The head of the narrow gorge marks the place where the present large-volume cataract resumed gorge making after the smaller cataract had made the narrower section. It is, therefore, a point of correlation with the lake history, for it was the uplift at North Bay, Ontario, which closed the outlet there and sent the discharge of the upper three lakes back to Lake Erie and Niagara. This point in the gorge marks that event, when the volume of the river was suddenly increased nearly sevenfold.

The Eddy Basin.—Half a mile north of the bridges the cliff line turns to the west and the gorge widens perceptibly. This wider part is the Eddy basin. The eddy with its large and gentle return current is in the foreground at the foot of the cliff, while on the far side billows dash across from the mouth of the narrow gorge above. The view to the north looks across the Eddy basin, and the reef and small rapids at its lower side toward the outlet of the whirlpool and the sharp separation of the two deep basins by the upper reef is clearly seen.

At Sinclair point the Eddy basin and the whirlpool may be seen. The contraction in the width of the gorge is as sudden and pronounced here as is the expansion above the railroad bridges. Lake Algonquin came to an end because the retreating ice sheet opened the outlet at North Bay, Ontario. Before this, Niagara had had the full discharge of the four lakes. But the opening of the new outlet took the discharge of the upper three away and left the discharge of Lake Erie alone, equal to only 15 per cent. of the previous volume. The contraction at the upper side of the Eddy basin marks this event in the lake history.

The Whirlpool from Sinclair Point.—Trees largely obstruct the view of the upper reef from this point, but

the view northward over the whirlpool is good. In the foreground one sees the tremendous in-rushing current on the right and the great return current on the left with a series of large whirls along the line of contact. One generally sees a considerable accumulation of flotsam in the whirlpool, made up largely of logs and timbers, and the powerful whirls may often be seen turning them on end and sucking them down beneath the surface.

At the far side of the whirlpool the high bluff of the drift mass that fills the ancient St. David gorge is revealed where a part of its face is exposed by a recent landslide.

The basin of the whirlpool is the headward part of

Looking northwest (down stream) from the Eddy basin across the Whirlpool, showing the short, sharp rapids caused by the Upper Reef, which separates the Eddy basin from the Whirlpool.

the buried St. David gorge and is of inter-glacial age. The reef at the outlet was left intact, because the east wall of the older gorge broke through before the boring power of the modern cataract was brought to bear upon the sandstone ledges. The reef separating the whirlpool from the

Eddy basin remains, because, after the older cataract had suddenly ceased the cliff line was driven back by weathering and was notched by a smaller stream, so that the renewed attack of the modern falls missed the ledges now forming the reef, and began their excavation just south of these ledges. Sinclair point is on the edge of the old drift bank of the river.

The Whirlpool from Thompson Point.—The best view of the whirlpool is from this point, where it is distinctly seen that the great current does not turn the sharp angle directly from the inlet to the outlet, but that its momentum carries it onward to the north side of the pool, where it strikes against the rocky wall of the older gorge and is deflected to the west or left in a great swinging curve. Continuing around the north and west sides of the basin, the whole great current turns toward the southeast and at a point opposite the outlet dives under the swifter current and reappears at the surface in the mouth of the outlet. Thus, substantially the whole volume of the river makes a great loop in which it turns backward and downward in order to find a way of escape.

From this point a better view is obtained of the upper reef and of the Eddy basin. The influence of the reef in producing a short, sharp rapids is clearly seen. The view down the river from this point is also fine, showing Foster rapids and the terraced slope on the left.

Wintergreen Terrace and Foster's Flats.—At this point one may descend into the gorge from the old drift bank of the river, first going down 15 or 20 feet (5 to 6 m.) to a flat area of limestone with almost no soil and only thinly covered with trees, a remnant of the old river bottom, which was scoured clean of drift before the falls had passed this point. At the north side of this terrace an overhanging cliff of limestone marks approximately a part of the crest line of the falls as they were at one time. Huge blocks have fallen from this cliff, but it still overhangs on the north, east and south sides enough to suggest the old crest of the falls. This part of the old river bottom was abandoned because a deeper channel was cut, more rapidly around the east side of the terrace.

Descending the stairway the path goes southward under overhanging cliffs, winding amidst great fallen blocks,

several of which contain remarkable potholes drilled by the spinning action of pebbles under the falling water of the cataract, probably after the blocks had fallen. Continuing to the west, the path descends to the cove, or Fisherman's eddy, a quiet spot a little above the turbulent waters of Foster rapids. The path is here on the Whirlpool sandstone. To the east, the ledges of this rock overhanging the turbulent waters of the rapids show, in a beautiful way, its cross bedding and laminated structure. At one or two places the path descends below the sandstone and rests on the Queenston shale, which is a soft, dark red mud rock. The contact of the sandstone, where it rests upon the shale, is well exposed and is remarkably sharp and abrupt. This path affords fine views of Foster rapids, some of the billows of which equal or surpass those of the Whirlpool rapids, and the channel here shows more obstructing rocks and reefs.

The path at length emerges upon a wooded terrace called Foster's flats, formed by the surface of the Whirlpool sandstone where the cataract was unable to penetrate it.

Returning, the path to the right is followed through Niagara glen, passing along the north side of a narrow, sharp ridge projecting towards the northeast. This part of the old river bed belonged to that part of the cataract which flowed over Wintergreen terrace. Another lower terrace formed by the Clinton limestone extends along the base of the eastern and southern sides of Wintergreen terrace and is largely covered with huge blocks of Lockport limestone fallen from above. Ascending, one gets a good idea of the size of some of these blocks where the path follows narrow passages between them or under their corners where they lie close together.

Soon after leaving Wintergreen terrace, a low drift bluff is seen running to the north. This marks the drift bank of the river when the falls were near Queenston. When about opposite Niagara university the gorge turns towards the north and grows slightly narrower. This point of correlation with the lake history is not so sharply defined as the two mentioned above, but it is believed that, during the Kirkfield stage of Lake Algonquin, Niagara had only the discharge of Lake Erie, and more than a mile of the gorge north of the university was made at that time. When the uplift of the land closed the outlet at Kirkfield and sent the overflow to Port Huron and Chicago, the

volume of Niagara river was greatly augmented, certainly by an amount equal to if not greater than the present St. Clair river. This point in the gorge appears to mark that event in the lake history and the stretch from the bend below the university to the upper side of the Eddy basin, but not including the whirlpool, constitutes the Lower Great gorge.

The Old or Lower Narrow gorge, looking south (up stream) from a point a little south of the mouth of the gorge near Lewiston. Track of New York Central railway in middle foreground. Lower end of Lower Great gorge at bend in distance. Niagara University at top on left. Water moderately turbulent, not placid as in Upper Great gorge or Lower Great gorge above Foster rapids.

Old Narrow Gorge and Smeaton Ravine.—Northward from the university the cliff lines are seen to be remarkably even and the width of the gorge very uniform. These characters extend for more than a mile. Towards the northern part of this stretch the railway makes a sharp detour to the west in order to get around Smeaton ravine, which was made by a diverted or side stream of the river in the early part of the Port Huron stage of Lake Algonquin, when the great cataract was making the gorge at and a little above the university. The rock floor above the

falls at that time was extremely flat and broad. A shallow trough leads southwest and south from Smeaton ravine to the old river floor north of Foster's flats. Across this a part of the river found its way for a long enough time to carve out the small ravine which was in all probability 300 or 400 feet (90 to 120 m.) longer than now, when it was first made, the main gorge walls having weathered back this much since then. It does not seem possible that this side ravine could have been made during the preceding Kirkfield stage of Lake Algonquin, when the volume of Niagara river was small.

The Oldest Gorge Section.—At about one-quarter of a mile (·4 km.) north of Smeaton ravine, the cliff line and the railway turn towards the northwest. Fine views into the gorge and out of its mouth over Lewiston and the Ontario plain are obtained here. The cliff lines are more irregular north of this point and the top width of the gorge is a little greater. Near the mouth of the gorge the walls are about 350 feet (106 m.) high, the capping limestone is only about 20 feet (6 m.) thick and over 100 feet (30 m.) more of shale is exposed. All of these factors favour more effective weathering and cliff recession and have produced wider talus slopes than in the newer parts of the gorge. The average top width for a little more than a mile north of the university is only a trifle less than the average width of both of the great gorge sections above. But the narrowness of this section at its bottom, coupled with the characters mentioned, indicates that it was originally narrow and not so deep, having been deepened largely in later times by the long wearing action of rapids or small cataracts and not by a great cataract. The gorge characters indicate that the river had a relatively small volume while making this section, which corresponds with the Kirkfield stage of Lake Algonquin, when Niagara had only the discharge of Lake Erie.

There is no great change in the characters of the gorge north of Smeaton ravine, but the point where it widens slightly [about 2,000 feet (600 m.) south of the mouth] is taken as a division point, not only on account of the slight widening and more irregular cliff line, but because other facts, showing the divided volume of the first flow of Niagara and the relatively brief duration of that condition, point to the same place. This point, if correctly identified, marks the time in the lake history

when the Kirkfield outlet first opened and early Lake Algonquin came to an end. Niagara river had a large volume during the making of the first 2,000 feet (610 m.) but it flowed over the escarpment at five different places, the stream at Queenston being probably the largest branch. So far as can be seen, however, this stream was only a little larger than the overflow of Lake Erie alone which made the next section to the south.

Brock's monument stands on the edge of the Niagara escarpment and commands a splendid view northward over the Ontario lowland, the lower reaches of Niagara river and Lake Ontario in the distance. On a clear day the bluffs at Scarboro a few miles east of Toronto are clearly visible, although nearly 40 miles (65 km.) away. In the foreground at the foot of the escarpment lies the village of Queenston and, on the east side, Lewiston. The waves of Lake Iroquois washed against the base of the escarpment south of Queenston and a shore cliff marks the ancient beach for several miles westward. It is seldom more than 25 feet (7 m.) high and is usually cut in the drift. The escarpment itself is a much more ancient feature.

The Cataract Bar at Lewiston.—At Lewiston will be seen the large gravel pits about 100 yards (90 m.) north of the station. The gravels seen in these pits are in several respects remarkable and are quite different from the usual types found in beach ridges, spits, deltas, or in kames or other glacio-fluvial deposits. They are remarkably clean and the pebbles are mostly well rounded though partly also subangular; and are set in steeply inclined beds which dip to the south or south-east in all parts of the excavation. Many of the layers are remarkably coarse, containing numbers of pebbles 6 or 8 inches (15 or 20 cm.) in diameter with occasional ones considerably larger. Some of the beds are composed of finer material but no fine sand is seen in the steeply inclined beds. Some of the coarser layers which have large inter-spaces with no filling of finer material between the pebbles were evidently set in place quickly by the action of powerful currents. No crossbedding or interruption of the layers has been found any where in the deposit, and as they were exposed a few years ago, the steeply inclined layers were seen to descend in even, parallel beds to a depth of 30 to 35 feet (9 to 11 m.).

In his guide book published in 1901 Prof. I. P. Bishop shows a photograph in which the inclined beds are seen to bend southward at their base into a nearly horizontal position.

A large amount of this gravel has already been removed, but it is exposed in the bank of the river for fully half a mile north, gradually thinning out in that direction. A smaller but precisely similar deposit with coarse southward dipping beds is exposed just opposite on the west side of the river. Gravels of the same coarse character extend southeast from the main street of the village to the Presbyterian church and the cemetery east of it.

Section of Cataract Gravel bar ar Lewiston, looking east. The gravels are largely coarse and the beds pitch to the south or southeast to a depth of 30 to 35 feet.

These gravels have generally been described as a part of the Iroquois beach formation. This beach extends through the village to the bank of the river at the gravel pit as a well formed spit, but here its composition and arrangement are of a somewhat different character. At the pit one sees that the highly inclined beds

are cut off abruptly at the top and that the fine gravel and sand of the Iroquois beach proper overlie them in an unconformable manner. About 100 yards to the southeast just west of the high school, the beach ridge, which is here in its original state, shows the form of the ridge very clearly. The coarse gravels in the south part of the village rise a few feet higher than the top of the Iroquois spit and show no evidence whatever of shaping or modification by wave action.

Directly south of these gravels and of the village there is a remarkable depression or basin which, from its general form and relations and from its situation just opposite the mouth of the gorge, seems explicable only as the result of the first plunge of the cataract over the escarpment. The terrace of Whirpool sandstone just at the mouth of the gorge was swept clean of all drift, while half a mile east it is covered with till, and many large blocks lie along the edge just below the sandstone terrace and the floor of the depression near the terrace. A knoll about 30 feet (9 m.) high which stands just north of it is literally paved with boulders set close together over the whole surface. The boulders grow fewer and smaller north and northeastward from the terrace, ending in coarse gravels. Farther north the great deposit begins at the pits opposite the station and extends half a mile north, with a smaller deposit also on the Canadian side. The outline of the basin, especially on its east side, is sharply defined by a bluff of drift 30 to 40 feet (9 to 12 m.) high which marks the eastern limit of excavation by the powerful currents from the cataract. On the Canadian side a channel runs through Queenston to the northwest and turns northeast to the river, completing the symmetry of the excavated basin which spreads in the shape of a fan from the mouth of the gorge. The basin is 30 to 40 feet (9 to 12 m.) deep in its deeper parts and the coarse gravels referred to form bars in its northern part and extend beyond its northern side. From these relations it might be concluded that the gravels were accummulated in their present form by the powerful currents which issued from the base of the cataract when it first plunged over the escarpment, and are therefore, true cataract gravel bars. Thus the inclined beds face towards the mouth of the gorge, as though powerful outrushing currents had rolled the gravel out from the base

of the cataract and up the face of the bar at the outer edge of the pool. It is, however, believed that the old interpretation is correct and that the peculiar features result from the coarse gravels at Lewiston having belonged to a spit of Lake Iroquois which migrated up the slope as the level of the lake rose 35 or 40 feet to the existing Iroquois spit at Lewiston.

Views in the Gorge from the Lower Level.—The car returns along the bank of the river and enters the mouth of the gorge about 40 feet (12 m.) above the water. The west wall is almost entirely clothed in forest, except for about 20 feet (6 m.) up from the water which was swept bare by the great ice jam of February, 1909. The current is only moderately swift near the mouth of the gorge, but grows swifter and rougher up stream. Up to the Catholic university the river is fairly uniform in width and velocity, but above the bend at the university, it grows much wider and much of it is evidently quite shallow. At the foot of Foster's flats the river begins to grow narrow until at the head of Foster rapids about at Wilson point the narrowest point in the whole river is passed, the surface width here being 300 feet (91·4 m.). The water at the head of Foster rapids descends in a cascade, almost a fall. Indeed, if the volume of the river were small, say one-seventh of the present volume, there would probably be a distinct fall or drop like the upper cascade near Sister island. The rapids just below are the most turbulent in the river and are beset with dangerous rocks.

Where the river widens abruptly just above Foster rapids, it becomes much deeper and the water is more quiet. The contraction at the exit of the whirlpool is quite noticeable and the lower reef which spans the river just here produces a short, sharp rapids. At the entrance of the whirpool there is another contraction and a more strongly marked reef than at the exit.

Leaving the Whirlpool the railway passes along the east side of the Eddy basin with rapids surging from the steep narrow gorge above in the foreground. The rapids do not lose all of their turbulence before they strike the upper Whirpool reef which again throws them into frothy billows. Looking from the car the sharp contraction of the width of the gorge at the upper side of the Eddy basin is quite striking. From the head of the narrows above the railroad bridges the river descends about 45 feet

(14 m.) to the whirlpool. Careful estimates indicate a depth of 35 to 40 feet (10·6 to 12·2 m.) in the lower part of the rapids, but Spencer's soundings indicate nearly twice this depth under the upper railroad bridge.

South of the railroad bridges the electric railway begins the ascent to the top of the Upper Great gorge. This climb affords magnificent views of the northern part of this section and of the place where it suddenly contracts and the narrower gorge of the Whirpool rapids begins. As the car climbs the wall of the gorge good exposures of the Clinton limestone, the Rochester shale and the Lockport limestone are obtained. Just after passing under the steam railway the surface of the limestone shows glacial polishing and scratching.

NIAGARA FALLS TO HAMILTON.

From the station on the Canadian side the train proceeds by the Grand Trunk railway to Hamilton. About a mile north of Niagara Falls, Ontario, the railway passes within a quarter of a mile of the western cliffs of the whirlpool and farther north crosses two or three sharp ravines of the headward streams of Bowman creek. Beyond this the view discloses no evidence of the buried St. David gorge. Instead, one sees to the east a level plain and fertile fields. At the head of the embayment south of St. David there is a great deposit of gravel which has been extensively excavated for ballast. These gravels are of glacio-fluvial origin and were deposited in connection with one of the slender moraines which crosses this region. In passing the gravel pits the cross bedding of the deposits may be seen from the train.

As it passes through the gravels the railway turns to the west and begins a long descent down the face of the escarpment. In a cut about a mile and a half (2·4 km.) west of the pits a few exposures of Lockport limestone may be seen and, about a mile farther on, the Rochester shale. Half a mile west of this and about a mile east of the Welland canal there is a fairly level terrace formed by the Whirlpool sandstone, but only small exposures of the rock are seen. Welland canal which is crossed next, is one of the largest and busiest canals on this continent. Continuing, the railway descends gradually to the flat clay plain below the Niagara escarpment. At

the station south of St. Catherines the railway descends to the lower side of a low bluff,the shore cliff of the Iroquois beach, which continues most of the way from Queenston to Hamilton. From the village of Homer, about three miles (4·8 km.) east of St. Catherines, the shore cliff gives place to a strong gravelly beach ridge which runs westward into St. Catherines where it divides into several spits. The shore again becomes a strong gravel ridge in crossing the embayment between Stoney creek and Bartonville.

The route of the railway westward from St. Catherines is over a flat plain which descends gently toward Lake Ontario but is deeply trenched by many small streams. The subsoil is of clay, but the surface is generally gravelly or sandy loam, excellent for agriculture purposes and especially for fruit growing. The climatic influence of Lake Ontario favours the same industry and a little farther west near Grimsby almost all the land is given to the raising of peaches, pears, apples and grapes, forming one of the best fruit growing districts in Canada.

Just west of Jordan station about seven miles (11·2 km.) west of St. Catherines, the railway crosses the drowned valley of Twenty Mile creek. North of the railway the valley of this creek is occupied by one of those landlocked lakes which arise from the backing up of the water into the valley after it had been cut down to a level lower than the present level of Lake Ontario.

Five or six miles (8 or 9·6 km.) west of Jordan, and at two or three places farther on, the railway passes through a bouldery or stony belt, sometimes with low small knolls of bouldery till. In places these appear to be the remains of a moraine which has been mostly washed away, corresponding probably to the Carlton moraine in New York; in others they mark the site of a beach ridge which was washed away when the lake rose to a higher level. At Queenston the Ontario lowland is eight or nine miles (13 or 14 km.) wide. At Jordan it narrows to three, and at Grimsby it is only one mile wide, but thence westward to Hamilton it is generally two to three miles wide.

IROQUOIS BEACH.

BY

A. P. Coleman.

GEOLOGY AND PHYSIOGRAPHY OF THE HAMILTON DISTRICT.

As shown in former pages by Mr. Taylor, the most striking physiographic feature of the Ontario region is the Niagara escarpment, which runs as cliffs facing northward from Queenston to Hamilton, then turns northeast to Waterdown, and finally bends to the northwest to the shore of Georgian bay. The cliff is due to the more rapid attack of the weather upon the soft underlying shales than upon the protecting layer of resistant limestone on top. It ranges in height from 300 to 400 feet (90 to 120 m.) above the plain which slopes gently down between its foot and Lake Ontario.

A short distance inland on each side of the lake there is a less conspicuous feature, to which reference has also been made—the old shore of Lake Iroquois, which occupied the basin toward the close of the Ice Age when the removal of the ice sheet had progressed as far as the Thousand Islands region, though the St. Lawrence valley beyond was still blocked.

The old shore of Lake Iroquois has been mapped by Gilbert and Fairchild in New York, and by Spencer and Coleman in Ontario; and it was early recognized by Dr. Spencer that the beach was no longer horizontal, but had been deformed by the upward warping of the earth's crust toward the northeast. It is commonly very well defined, with cliffs and gravel bars as mature as those of the present lake. At Lewiston and Queenston, as mentioned before, its level is about 125 feet (38 m.) above Ontario, but at Hamilton its height is 116 feet (35·4 m.) and at Toronto 176 feet, (53·6 m.) toward the west and 200 feet (61·0 m.) toward the east. Between Hamilton and Toronto its deformation is at the rate of 2 feet per mile (·38 m. per km.). To the east of Toronto it increases to 3·4 feet and at the far northeastern end reaches 5 or even 7 feet per mile, its last observed point rising 495 feet (150·8 m.) above Lake Ontario. The

Iroquois beach is made use of on each side of Lake Ontario by the main roads, from Queenston to Hamilton and from Hamilton via Dundas street to Toronto. Its old gravel bars are occupied by three cities, St. Catherines, Hamilton and parts of Toronto, though the two larger cities are now spreading far beyond the old shore.

In a few places the Iroquois beach lies at the foot of the escarpment, which must have formed magnificent cliffs against which the waves dashed, but in general its shore cliffs are low and were carved in boulder clay, or more rarely in the soft red Queenston shale.

PHYSICAL FEATURES AT HAMILTON.

The city of Hamilton lies mainly on the Iroquois terrace between the Niagara escarpment to the south and Hamilton bay (or Burlington bay) to the north. The bay, which is about 5 miles (8 km.) long and 4 miles (6·4 km.) broad toward the east, is cut off from the western end of lake Ontario by a very straight gravel bar 4 miles (6·4 km.) long, called Hamilton beach. This is cut by a short canal giving access to the bay, which is in places 78 feet (23·8 m.) deep and forms an excellent harbour. The modern Hamilton bay repeats in essential respects the Dundas bay of lake Iroquois just to the west.

The escarpment to the south of the city, generally called Hamilton mountain, rises in places to 650 feet (200 m.) above the sea, more than 400 feet (122 m.) above Lake Ontario. The upper part of the cliff, formed of the firm Niagara (Lockport) limestone rises boldly, but the lower part of the escarpment is largely hidden by talus. A full description of the section exposed here with the fossils which may be collected from the different formations, will be found in the guide book to Excursion B3. South of the escarpment a tableland generally covered with boulder clay rises gently.

From the top one can look down upon the thriving city, the bay and beach, and the shores of Lake Ontario can be followed by the eye for many miles to the east and to the northeast. Toward the north one sees the ancient gravel bar of Burlington Heights, three miles (4·8 km.) long and with a gentle westward curve. To the west of it stretches Dundas marsh, threaded by the long unused Desjardins canal,which once allowed small

vessels to reach the town of Dundas, three miles (4·8 km.) west of Hamilton bay. The old shore of Lake Iroquois can be observed stretching round to Dundas; but its western end is poorly marked in a region of hummocky morainic material where the Ontario lobe of the last ice sheet made its way up an ancient valley cutting the escarpment. Beyond the depression of Dundas bay the escarpment rises in imposing cliffs which turn off to the northeast and after a few miles bend northwards.

Descending the escarpment one passes first the thick sheet of Niagara limestone (Lockport) then the softer gray shales (Rochester) and reaches the Clinton limestone beds, much thinner than the Niagara limestone above. Below this come the gray Cataract sandstone and the red Richmond or Queenston shale, which underlies the talus near the foot of the escarpment and is largely hidden.

The slope occupied by the city between this and the shore of Hamilton bay is formed mainly of Iroquois beach deposits, sand and silt, well stratified and often 20 feet (6 m.) or more thick, as shown in excavations. Rarely the red shale may be seen in unusually deep cuttings.

THE IROQUOIS BEACH AT HAMILTON.

Descending the escarpment toward the east end of the city one stands upon the Iroquois terrace at the foot of what must have been a fine shore cliff 300 feet (90 m.) high. The old beach can be followed westward for a mile at the foot of the cliff and then bends northwest as a gravel bar through the highest part of the city, passing Dundern park and the cemetery and running nearly north as an extraordinary embankment of sand and gravel, less than a quarter of a mile (·4 km.) wide and 116 feet (35·4 m.) high. The bottom is of sand and the upper 66 feet (20·2 m.) of coarse sand and gravel, partly cemented to conglomerate by the deposit of lime between the pebbles. In general the stratification runs horizontally and with great uniformity. At Desjardins canal, an artificial cut across the bar, it is seen in cross section that the materials are often crossbedded. Beyond the canal, which is crossed by railway and road bridges, the bar curves somewhat east of north and ends at the former outlet of the Dundas marsh, now filled in with a railway embankment. The bar evidently pushed out from the

foot of the cliff formed by the escarpment across the mouth of the Dundas bay while the water of Lake Iroquois stood perhaps 100 feet (30 m.) lower than its final stage. As the northeast end of the lake warped upwards the water rose toward the west end and the bar grew in height to correspond, till it reached its present wall like form.

To the west of the bar a plain 36 feet (11 m.) lower consists of stratified clay, sand and gravel deposited in the bay, and extending to the town of Dundas. At various places in the gravel bar and the beds to the west fossils have been found including mammoth, wapiti and beaver. The most common fossils are bones, ivory and teeth of mammoth, which occur at various levels, from 33 feet (10 m.) to 70 or 80 feet (21 to 24 m.) above Lake Ontario. An old soil with mammoth bones and remains of trees was found 30 feet (9·1 m.) below the gravel bar in the city, showing a decidedly lower stage of water before the final beach level was attained.

The rise of water at the west end of Lake Iroquois corresponded in character to the later rise in Lake Ontario, leading to the flooding of the lower portions of the rivers and to the growth of Hamilton beach in water now 78 feet (23·8 m.) deep. It appears that there has been a more or less continuous elevation toward the northeast since the departure of the ice, probably with a gradual slowing down until at present the change of level is very slight or completely ended.

The Grand Trunk railway from Hamilton to Toronto follows the Burlington gravel bar to the north shore of the old bay, where red shales begin to show themselves under a shallow deposit of drift. At Waterdown, four miles (6·4 km.) east of Hamilton, another gravel bar of Iroquois age projects two or three miles toward Hamilton bay, to some extent overlapping the great bar just described. The channel of the stream which flowed from the Dundas valley before the cutting of the Desjardins canal seems to have been an entrenched meander dating from Iroquois times.

The railway runs for about 15 miles (24 km.) a little to the south of the Iroquois shore, which can be seen rising as a low cliff from the plain which slopes gently towards Lake Ontario. The rest of the railway journey to Toronto is near the present lake shore and out of sight of the old beach.

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EXCURSION A 12.

THE PALÆONTOLOGY OF THE GUELPH, ONONDAGA AND HAMILTON FORMATIONS IN WESTERN ONTARIO.

BY

WILLIAM A. PARKS.

With Sections by C. R. STAUFFER and M. Y. WILLIAMS.

CONTENTS.

INTRODUCTION.

The comparatively flat upland of the southwestern part of the Province of Ontario is separated from the eastern lowland by the Niagara cuesta which extends from Queenston on the Niagara river to Hamilton at the head of Lake Ontario and thence into the Bruce peninsula between Lake Huron and Georgian bay. The brow of the cuesta is marked by the Lockport (Niagara) dolomite which extends only a short distance back from the edge of the escarpment.

The yellow dolomites of the Guelph formation succeed the Niagara rocks and form a belt about 30 miles (48 km.) wide with a length of 80 miles (129 km.). The actual extent of the formation is probably much greater than this, but the evidence is not very satisfactory owing to the heavy covering of drift. Excellent exposures from which the unique fauna of the formation may be collected occur at Guelph, Galt, Hespeler, and at points farther north.

West of the Guelph formation, the unfossiliferous shales and limestones of the Salina stretch in a broad band from the Niagara river to Lake Huron. The western boundary of this formation runs approximately from Fort Erie to Goderich. Gypsum quarries are located on this formation in the vicinity of Caledonia and Paris, while at Goderich and Windsor it is the source of a large amount of salt.

The Salina is succeeded by the Monroe formation which constitutes the summit of the Silurian series: it is composed largely of dolomitic limestones and is separated into an upper and lower member by a median bed of sandstone (Sylvania). Exposures of this formation are infrequent in Ontario: an unfossiliferous type is seen in the "waterlime" of the Niagara district while a fossiliferous dolomite with an interesting Silurio-Devonian fauna is exposed by the Livingstone cut in the Detroit river opposite Amherstburg. The Sylvania sandstone has no areal extent in Ontario but it is always penetrated in drilling the salt, gas and oil wells of the western part of the province.

The Oriskany sandstone, with a small but unique fauna, marks the opening of Devonian time: the formation

is of very limited thickness and is exposed, over a small area only, in the eastern part of the region.

The Onondaga (Corniferous) is the chief Lower Devonian formation: it consists largely of limestone which is highly fossiliferous in places. This formation forms the greater part of the province west of the Salina boundary: it is divided into two areas by a broad belt of Middle Devonian strata (Hamilton) which overlies it. This belt consists largely of shales with some intercalated limestones and presents, in places, an extraordinary profusion of excellently preserved fossils.

The highest member of the Devonian series in Ontario is exposed on the shore of Lake Huron near the south end. The rocks are highly bituminous shales, but fossils are rare or confined to a few obscure plant remains. The rocks are commonly ascribed to the Genessee shale of the Portage and Chemung formations of the New York geologists.

It will be seen from the above sketch that the interesting formations from a palæontological point of view are the Guelph, the Onondaga and the Hamilton. The excursion is planned to afford an opportunity for collecting on these formations as below:

Oriskany and Onondaga—Hagersville and vicinity.
Hamilton—Thedford and valley of Aux Sables river.
Guelph—Guelph, Hespeler and Galt.

TABLE OF FORMATIONS.

The Silurian and Devonian formations of western Ontario are as follows:

Upper Devonian—Genesee shales.
Middle Devonian—Hamilton.

Lower Devonian	Onondaga. Oriskany.
Upper Silurian	Upper Monroe. Sylvania. Lower Monroe.
Middle Silurian	Salina. Guelph. Niagara.

ANNOTATED GUIDE.

Miles and Kilometres.

0. m. 0 km. **Toronto.**—Alt. 254 ft. (77·2 m.). Leaving Toronto, the railway crosses the Humber river immediately to the west of the city. The slack water in the lower reaches of this river and of the other streams at the west end of Lake Ontario is due to the backing of the waters of the lake owing to a differential elevation of the rock basin at the eastern end in post-Glacial times. The clay exposures in the vicinity of the Humber consist of inter-glacial materials worked over by post-glacial agencies.

6·42 m. 10·3 km. **Mimico.**—Alt. 300 ft. (91·2 m.). At Mimico, quarries in the Lorraine shales may be seen to the north of the track: exposures of the same rocks occur in the bed of the Etobicoke river beyond.

13·1 m. 20·9 km. **Credit.**—Alt. 265 ft. (80·6 m.). The invaded valley of Credit river is comparable with that of the Humber. No rock is exposed here, but in this vicinity the Lorraine shales give place to the overlying red shales of the Richmond formation which continue to Hamilton and are exposed in many small valleys along the line of the railway. Beyond the Credit river, the north shore of the post-glacial Lake Iroquois (Iroquois beach) is plainly to be seen along the north side of the track all the way to Hamilton.

31·78 m. 50·8 km. **Burlington.**—Alt. 328 ft. (99·7 m.). At Burlington the flat bottom of Lake Iroquois is well shown with the Iroquois beach beyond, and above that the escarpment of the Niagara cuesta.

Just before entering Hamilton, the gravels of the Burlington beach (Iroquois) may be seen resting on the red Richmond shales. (See guidebook to Excursion A4). At this point, the Desjardins canal is crossed: it marks approximately the position of a pre-glacial river which discharged into the Ontario basin.

Miles and Kilometres.

38·83 m. 62·1 km. **Hamilton.**—Alt. 253 ft. (76·9 m.). On leaving Hamilton, the railway at once begins the ascent of the Niagara cuesta. In a distance of five miles (8 km.) an elevation of 383 feet (114·7 m.) is attained. The formations exposed in the face of the cuesta are in ascending order as follows:—

Richmond—Red shales, covered largely by talus.

Cataract—Basal sandstone and overlying limestones and shales. Quarries near the inclined railway at the head of Wentworth street are in the basal sandstone.

Medina—Mottled and white sandstones. Not observable from train.

Clinton—Limestones and shales. } Thin and doubtfully present.
Rochester—Shales. }

Lockport (Niagara)—Dolomites. Seen in cut near top of grade. (See guide book, Excursion B3.)

From the left-hand windows, a glimpse may be had of the splendid fruit lands which extend, undei the protection of the cuesta, from Hamilton to the Niagara river.

44·98 m. 71·9 km. **Rymal.**—Alt. 644 ft. (195·7 m.). At Rymal, the railway has reached the level of the upland: differences in elevation are slight between this point and Lake Erie. Extensive quarries in the Niagara dolomite were formerly operated near Rymal.

55·03 m. 88·05 km. **Caledonia.**—Alt. 652 ft. (198·2 m.). In the short distance between Rymal and Caledonia the Niagara-Guelph and the Guelph-Salina contacts are crossed, but the heavy mantle of drift permits of no exposures being seen.

An important gypsum quarry has been sunk to a depth of 80 feet (24·4 m.) in the Salina

Miles and Kilometres.

rocks near Caledonia. The section presented in the shaft is as follows:—

Drift..............	10 feet (3 m.)
Limestone.........	20 feet (6 m.)
Gypsum...........	4 feet (1·2 m.)
Shale and limestone.	34 feet (10·3 m.)
Anhydrite.........	4 feet (1·2 m.)
Gypsum...........	7 feet (2·1 m.)

64·53 m. **Hagersville.**—Alt. 729 ft. (222·6 m.). The
103·3 km. Pleistocene deposits between Rymal and Hagersville are but slightly modified glacial débris with post-glacial gravels and sands at certain points.

GEOLOGY OF THE REGION AROUND HAGERSVILLE.

BY

CLINTON R. STAUFFER.

GENERAL DESCRIPTION.

Hagersville is located in the midst of a comparatively level tract of land, although to the north and east the country becomes somewhat rolling. This region is a part of the glacial plain over which the marginal lakes of the receding continental glacier spread. The effect of this water action, however, has been slight and the flatness of the region is due, chiefly, to the position of the underlying bed rock, for the drift covering is often very thin. The land, especially to the south, is excellent for agricultural purposes, the chief crops being wheat, oats and hay. Ten miles (16 km.) to the southwest lies the famous fruit region of Norfolk county where some of the finest apples grown on the North American continent are produced.

The main street of Hagersville is the Old Indian Line which separates the white man's land from that of the red man, the latter being allotted that to the northeast. The reservation has been somewhat reduced by purchase, so that now it lies entirely to the north of town. Other

than the copper coloured skin of many of the occupants, there is little about the Indian's land to suggest its ownership, for he has learned to till the soil in much the same way that other farmers do.

The rocks to be seen near Hagersville are chiefly of Devonian age, although the Silurian-Devonian contact comes to the surface but a short distance to the north and east. A notable feature of the Devonian outcrops is their terrace-like occurrence. These are perhaps remnants of old rock terraces connected with the buried pre-glacial valleys, the upper portions of which have been but partially obliterated by drift deposits. The outcropping formations of this immediate vicinity may be grouped together in the following classification; (**9**.)

Devonian	Onondaga.	Onondaga limestone.
		Springvale sandstone.
	Oriskany sandstone.	
Silurian	Cobleskill dolomite (?)	
	Salina beds.	

SALINA BEDS.

The beds, of Salina age, lying immediately below the Devonian of this region are probably the Bertie waterlime. At some places there may be remnants of the Cobleskill, but this is an uncertain matter, as the fossils so far obtained are not conclusive. The Salina beds consist of drab (weathering buff to yellowish brown) to bluish compact dolomites passing into shales and gypsum-bearing deposits below. At some places, these Silurian deposits include thin streaks of sand, while at the top, the coarse sand from the Oriskany has penetrated the cracks and crevices in all directions, there consolidating into thin seams of sandstone. The Silurian-Devonian contact is uneven and the rocks underneath often show the effects of pre-Devonian weathering.

ORISKANY SANDSTONE.

The Devonian often begins with a basal conglomerate composed of sub-angular and rounded pebbles of the Silurian dolomites mingled with sand, the whole cemented into a solid mass. The thickness of this conglomerate

is rarely more than six inches (15·2 cm.) to one foot (30·4 cm.) and it is frequently absent. Where found it usually grades into the overlying deposits without a break. Southeast of Hagersville these overlying deposits are beds of true Oriskany sandstone (**10**). At most other places they belong to the Onondaga limestone. The Oriskany (**3**) is usually composed of moderately coarse-grained quartz sand but it is often much coarser and sometimes even pebbly, the individual grains of which are as much as an inch in diameter (**5**). Some parts of the rock are so closely cemented by silica that it resembles a quartzite in appearance. The rock is usually massive and sometimes the entire formation appears as a single bed. The total thickness of the Oriskany sandstone rarely exceeds 20 feet (6·1 m.) and much less is the usual rule. Although a large part of the deposit is almost barren, fossils are often abundant and in a good state of preservation, even the spires of certain brachiopods and the finest external markings being preserved.

Where the true Oriskany sandstone is absent, there is sometimes found a deposit of several feet of chert which has been assigned to the same formation as the sandstone (**5**). However, the fossils so far found in it are so rare and fragmentary that its true age is somewhat in question.

ONONDAGA.

The Onondaga limestone usually rests on an eroded Silurian surface, but occasionally it lies unconformably on the Oriskany sandstone. Where the latter is the case, the unconformity is marked chiefly by the change in fossils, but at some places there may be found a well developed conglomerate in which fossiliferous pebbles of Oriskany sandstone are mingled with the remains of Onondaga corals and fishes.

Where the Oriskany is absent the conglomerate persists, but at such places the pebbles are of Silurian dolomites. The lower portion of the Onondaga limestone, in this region, is usually arenaceous and very cherty. Sometimes the sand is so abundant that the deposit becomes an arenaceous chert, and again a true sandstone. This latter is the case at Springvale, where the lower portion of the Onondaga takes on such a marked resemblance to the true Oriskany that it has often been confused

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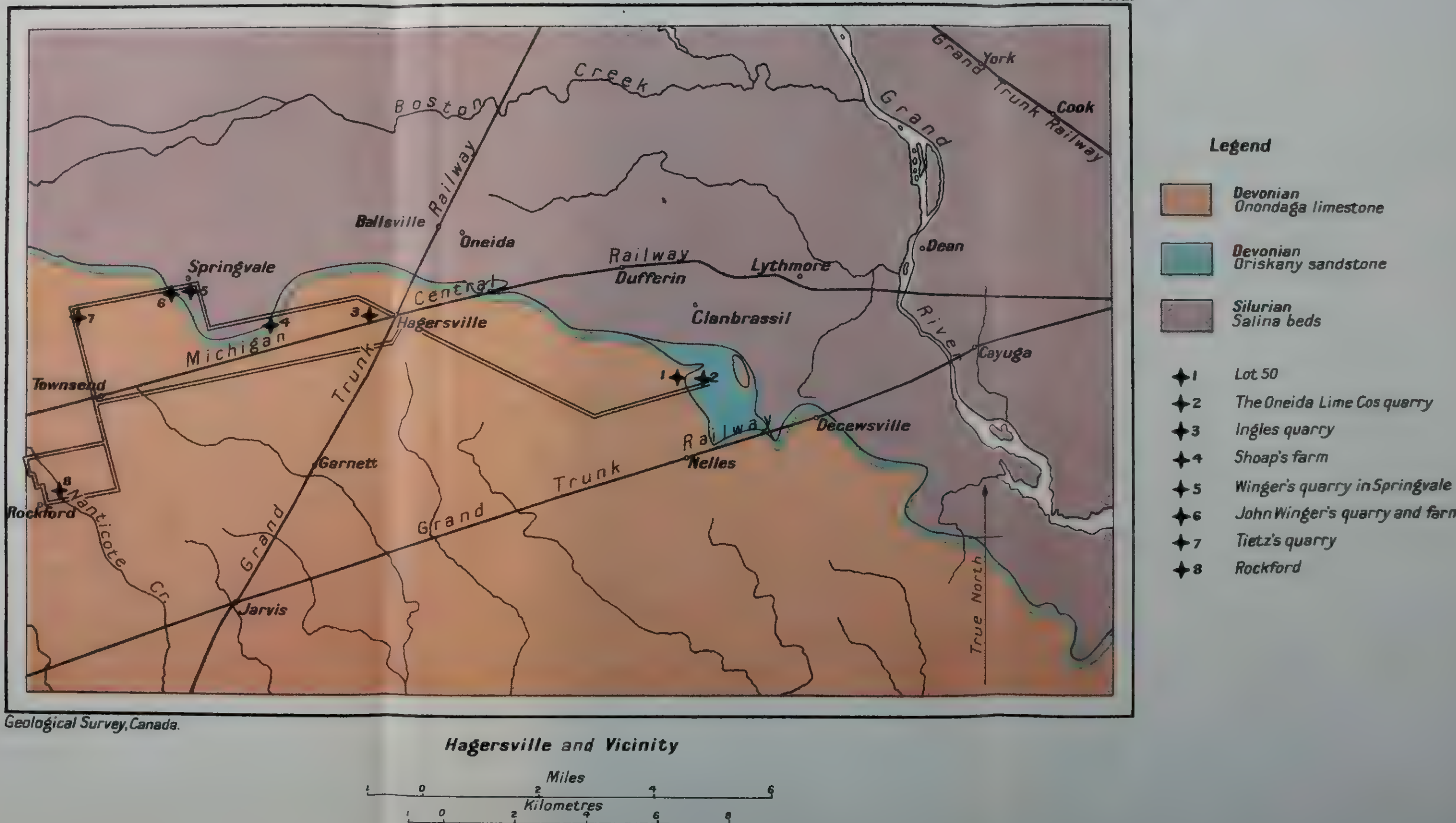


Geological Survey, Canada.

Hagersville and Vicinity

with it. The fauna, however, is Onondaga (**10**) in every characteristic and cannot be confused. But, because of the decided lithological difference from the ordinary appearance of the formation to which they belong, the beds are here referred to as the Springvale sandstone. This sandstone has a thickness of about 8 feet (2·44 m.) and the material of which it is composed was doubtless derived from the Oriskany sandstone, portions of which were re-worked by the advancing Onondaga sea. The Springvale sandstone is succeeded by cherty grey and bluish limestones attaining a thickness of over 60 feet (18·3 m.) in the vicinity of Hagersville. This mass is all rather fossiliferous: at some horizons the remains of corals especially occur in great abundance.

ONEIDA QUARRIES.

Five and three quarter miles (9·2 km.) southeast of Hagersville, on Lot 49, Concession 1 of Oneida township in Haldimand county, the Oneida Lime Company has several interesting quarries. At several places along the roadway from Hagersville (old Indian line) the cherty layers of Onondaga limestone come to the very surface. At Gill, 3·75 miles (6·04 km.) southeast of Hagersville the road turns east at the brink of one of the terrace-like outcrops of Onondaga limestone above mentioned.

On the southern part of Lot 50, Concession 1 of North Cayuga, the Oriskany sandstone comes to the surface and has been quarried on a limited scale. The uneven contact with the Silurian may be seen here while the surface of the sandstone shows the effects of glaciation. The rock is abundantly fossiliferous and, near the old barn at this point, its surface is literally paved with *Stropheodonta magnifica* Hall. If this ledge of sandstone is followed eastwards into the woods, other excellent outcrops will be found and also a greater variety of fossils.

At the cross-roads, a short distance to the east, are the quarries and plant of the Oneida Lime (and Sand) Company. Here a greater thickness of the sandstone may be observed as well as a small quarry in the Silurian limestone.

The massive Oriskany sandstone overlying the Silurian dolomites unconformably, near the Oneida Lime Company's quarry.

The following is a combined section measured at this place:—

	Thickness Feet.	Metres.
6—Soil and drift	1·5	·152
Onondaga limesione.		
5—A very cherty, bluish-grey limestone in which fossils are abundant. Much loose material, weathered out of these beds, occurs in the fields to the north, where collecting is good	3·6	1·118
4—Cherty, calcareous layers with an abundance of coarse sand intermingled. This portion sometimes becomes a true conglomerate in which the pebbles are fossiliferous Oriskany sandstone	0·6	·203
Oriskany sandstone.		
3—Coarse sandstone, partly covered	2·5	·763
2—Coarse grained, friable, white to yellowish sandstone with an abundance of fossils in certain spots. At some places, especially in the upper part, this sandstone contains occasional concretion-like bodies, which have been cemented into masses resembling quartzite. The contact of this sandstone with the underlying rock is very uneven, and the lower layers of sandstone contain sub-angular and rounded fragments of the underlying limestone. The thickness varies much from place to place	17	5·185
1—Buff to brown and drab dolomitic limestones which are rather compact and usually distinctly banded. These beds extend to the bottom of the limestone quarry and contain a few fossils	16·5	5·033

The fossils occurring in the different strata at this point are indicated in the first column of the table on page 92.

Onondaga Quarries about Hagersville.

Section at the J. C. Ingles quarry, Hagersville—An excellent section, entirely within the Onondaga limestone, is exposed in the quarry of J. C. Ingles at the

northwestern edge of Hagersville (8). The strata exposed are as follows:—

	Thickness Feet.	Metres.
6—Soil and drift	1	·305
5—A grey to brownish blue, semi-crystalline limestone containing much dark bluish chert. The layers are inclined to be rather massive, but, where weathered, split into thin uneven layers, which are sometimes shaly. Corals and crinoid fragments are abundant	9·16	2·796
4—Shaly parting, not always conspicuous	0·08	·025
3—Bluish grey, semi-crystalline limestone, containing a relatively small amount of grey to white chert. The whole mass is abundantly fossiliferous and sometimes even matted with corals	4·6	1·424
2—A dark bluish-grey, fine-grained limestone practically free from chert. The fossils are much less abundant than in the layers above. The upper four inches are often shaly and sometimes shaly partings occur between beds in the upper part.	6·83	2·085
1—Rough, cherty, bluish limestone to the level of water in the lowest water hole	6·25	1·906

The fossils that may be obtained from the five horizons indicated above are given in the second column of the list on page 92.

Oriskany and Onondaga at William Shoap's quarry.—Near Mr. Shoap's house, about a mile and a half westward from Ingles' quarry, a small run falls over a ledge of Springvale sandstone and cherty Onondaga limestone. There is thus preserved a good exposure of both formations, together with some of the underlying beds. The section at this point is as follows:—

	Thickness Feet.	Metres.
5—Soil and drift	4	1·22
Onondaga limestone.		
4—Cherty, blue to grey limestone. This rock is mostly chert and quite fossiliferous. In the upper part of these beds the corals		

	Thickness. Feet.	Metres.
stand out in relief on the matrix. Near the northeast corner of the house there is exposed a glaciated surface, on which sections of the corals show beautifully....	5·5	1·677
Springvale sandstone.		
3—Coarse white to yellowish sandstone. The lower portion of these beds is rather massive, while the upper layers are somewhat irregular and seem to contain more fossils...	8	2·44
Oriskany (?) cherts.		
2—Arenaceous blue shale..............	·58	·175
1—Irregular beds of bluish-grey chert with a few thin calcareous layers. These lower beds contain only a few fragments of fossils and extend to the bottom of the section in the run..........................	3·16	·966

The list of fossils from this locality is given in the third column on page 92.

Section at Springvale.—The slight terrace to the west of the highway near Springvale is caused by the same sandstone ledge that has just been observed at the last section. It lies under a very thin covering of drift and influences the topography for a distance of several miles. In the sugar-bush at the southern end of the village is one of the best gas wells of the locality. It is the chief source of fuel for the lighting and heating of this community. In the village proper is an old quarry and limekiln, in which about 10 feet (3·05 m.) of Silurian dolomite is exposed. These rocks contain a few fossils, such as *Ortholhetes hydraulicus* Whitfield, *Goniophora dubia* Hall, *Leperditia alta* Conrad, etc., which tie them to the Monroe group of the western part of the peninsula.

On John Winger's farm, one half mile west of the village, and at a number of other places along the ridge the Springvale sandstone has been quarried for local use, so that nearly the entire thickness may be seen. In the fields above the quarry the higher beds of the Onondaga are just under the surface, outcropping here and there, and fossils from it are scattered over the surface in great abundance. The most common of these are specimens of the

the large compound corals. This is especially true 100 yards (91·5 m.) along the hill-slope above the sandstone quarry. The section at this point is as follows :

	Thickness. Feet.	Metres.
Onondaga limestone.		
4–Cherts and cherty grey limestone weathering out over the hill side. The upper part contains an abundance of corals chiefly of the compound type..............	15	4·575
3–Arenaceous cherts weathering out in the field................................	·5	·153
2–Arenaceous grey limestone which becomes chiefly sandy in the lower part......	1·5	·458
Springvale sandstone.		
1–Yellowish to white coarse sandstone containing hard masses resembling quartzite. These layers are best exposed in the quarry face................................	5·5	1·678

The more common fossils found in the rocks on Winger's farm are indicated in the fourth column of the table on page 92.

Section at the Teitz quarry.—On the Teitz farm, about two and a half miles (4 km.) west of Springvale, quarrying operations have revealed a ridge of limestone which lies under a very thin covering of drift. Although the thickness of rock exposed here is slight, the bottom layers extend downwards to about the horizon of the top of the section on Mr. John Winger's place and thus form almost a continuation of that section. The section is as follows :

	Thickness. Feet	Metres.
4—Weathered, cherty limestone which may have been slighly moved.............	·5	·153
3—A semi-crystalline, grey limestone filled with the smooth variety of *Snathophyllum simcoense* (Billings), and having a few thin layers of chert in it..................	3·5	1·068
2—Semi-crystalline, grey limestone alternating with beds of soft, shaly, bluish-grey limestone. The semi-crystalline layers are usually very crinoidal and contain a good many corals, while the shaly layers contain *Hindia fibrosa* (Roemer)	2·5	·763

	Thickness. Feet.	Metres.
1—Four to six inch layers of blue to bluish-grey, semi-crystalline limestone in which fossils are not abundant...........		2·61

The fossils from Teitz' quarry are given in the fifth column of the table on page 92.

Section of Onondaga at Rockford.—At the mill at the edge of the little village of Rockford, there is a splendid natural exposure of the Onondaga limestone where the creek plunges over a small ledge of rock and a good oportunity to collect fossils is offered. The section follows :

	Thickness. Feet.	Metres.
4—Soil and drift..................	3	·915
3—Uneven bedded, bluish-grey limestone with a considerable quantity of grey chert. Along the west side of the outcrop these beds seem to come down on the bottom beds...	9·5	2·998
2—Semi-crystalline, bluish-grey limestone with a very little chert and full of fossil corals. These layers seem to pinch out out to the west	6	1·83
1—Dark bluish layers of limestone which are fully half chert. These layers present a rough appearance and extend to the bottom of the rock outcrop in Nanticoke creek....		2·61

The fossils from the three horizons at Rockford are given in the last column of the table on page 92.

List of Oriskany and Onondaga fossils.

	I			II					III		IV				V			VI		
	Oneida Lime Company's Quarry.			Ingles' Quarry.					Shoap's Quarry.		John Winger's Quarry.				Teitz's Quarry.			Rockford Quarry.		
Horizon	2-3	4	5	1	2	3	4	5	3	4	1	2	3	4	1	2	3	1	2	3
Hindia fibrosa *Roemer*																x				
Stromatoporella granulata *Nicholson*		x	x		x										x	x				x
Stromatoporella (?) tuberculata *Nicholson*								x							x	x			x	x
Acrophyllum oneidaense *Billings*		x												x						
Amplexus yandelli *E. and U.*		x	x																	
Aulopora cornuta *Billings*																			x	
Blothrophyllum decorticatum *Bill.*		x	x		x			x		x	x		x	x			x			
Cayugæa whiteavesiana *Lambe*								x											x	
Chonophyllum magnificum *Billings*																x				
Chonostegites clappi *E. and H.*			x							x				x						
Cladopora cryptodens *Billings*		x	x											x					x	x
Cladopora expatiata *Rominger*														x						
Cladopora francisci *Davis*														x						
Cladopora labiosa *Billings*		x	x			x				x				x	?		x		x	x
Cladopora pinguis *Rominger*														x						
Cladopora pulchra *Rominger*																			x	
Cladopora robusta														x						
Cladopora turgida *Rominger*														x						

Clisiophyllum conigerum *Rominger*																	x			
Cyathophyllum anna (*Whitfield*)																x				
Cystiphyllum aggregatum *Billings*														x						
Cystiphyllum sulcatum *Billings*			x								x									
Cystiphyllum vesiculosum *Gold*		x	x		x	x		x		x	x		x	x	x	x	x	x	x	x
Diplophyllum arundinaceum (*Bill*)																			x	
Eridophyllum colligatum *Billings*)														x		x	x			
Eridophyllum verneuilanum *E. and H.*			x											x						
Favosites basalticus *Goldfuss*			x					x		x				x	x	x	x	x		x
Favosites canadensis *Billings*								x						x		x	x		x	
Favosites cervicornis *E. and H.*				x				x									x	x	x	x
Favosites clausus *Rominger*			x													x				
Favosites conicus ? *Hall*	x																			
Favosites emmonsi *Rominger*			x	x	x	x		x	x	x	x		x	x	x	x	x	x	x	x
Favosites epidermatus *Rominger*			x					x						x		x	x			x
Favosites goodwini *Davis*														x						
Favosites helderbergiæ *Hall*	x																			
Favosites limitaris *Rominger*			x						x	x				x		x	x		x	
Favosites radiciformis *Rominger*																x			x	
Favosites tuberosus *Rominger*														x						
Favosites turbinatus *Billings*		x	x		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
Favosites winchelli *Rominger*					x									x	x	x				
Heliophyllum annulatum *Hall*																			x	
Heliophyllum corniculum (*Lesueur*)			x			x		x		x				x			x			
Heliophyllum exiguum *Billings*			x						x	x	x			x						
Heliophyllum fecundum *Hall*																x				
Heliophyllum halli *E. and H.*			x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x
Michelinea convexa *d'Orbigny*		x	x		x	x				x	x			x	x	x				
Michelinea favositoidea *Billings*			x							x				x						
Phillipsastrea gigas *Owen*			x						x					x		x				
Phillipsastrea verrilli *Meek*														x						
Pleurodictyum problematicum *Gold*										x										
Snathophyllum simcoense (*Billings*)			x			x		x	x	x				x		x	x	x	x	x

List of Oriskany and Onondaga fossils.

	I			II					III		IV				V			VI		
Horizon	2-3	4	5	1	2	3	4	5	3	4	1	2	3	4	1	2	3	1	2	3
Snathophyllum stramineum *E. and H.*																			x	
Syringopora hisingeri *Billings*			x	x	x	x				x	x			x	x	x				
Syringopora maclurei *Billings*			x												x	x	x			
Syringopora perelegans *Billings*		x	x	x		x		x	x	x				x	x	x	x	x		x
Syringopora tabulata *E. and H.*					x															
Zaphrentis davisana *Miller*																	x			
Zaphrentis gigantea *Lesueur*		x	x	x	x	x		x	x	x	x	x		x		x		x		x
Zaphrentis nodulosa *Rominger*														x						
Zaphrentis prolifica *Billings*			x						x	x	x	x		x	?	x	x			x
Zaphrentis rœmeri *Hall*	x																			
Cystodictya gilberti (*Meek*)		x	x						x		x									
Fenestella biseriata ? *Hall*	x																			
Fenestella erectipora					x			x												
Hederella canadensis (*Nicholson*)														x						
Hederella magna ? *Clarke*	x																			
Isotrypa conjunctiva (*Hall*)														x						
Monotrypa tenuis (*Hall*)												x								
Monotrypella sp	x																			
Pinnatopora tenuistriata (*Hall*)					x															
Polypora hexagonalis ? (*Hall*)	?				x															
Polypora robusta (*Hall*)		x	x											x			x			
Amphigenia elongata (*Vanuxem*)	x	x	x		x				x	x	x	x	x	x		x				
Anoplia nucleata *Hall*	x	x	x								x									
Anoplotheca camilla (*Hall*)		x	x		x					x				x						

Anoplotheca flabellites (*Conrad*)	x													
Atrypa reticularis (*Linnæus*)	x	x	x	x	x	x	x	x	x	x	x		x	x
Beachia suessana *Hall*	x													
Brachyprion schuchertanum ? *Clarke*	x													
Camarotoechia barrandei *Hall*	x													
Camarotoechia billingsi *Hall*			x					x	x				x	
Camarotoechia carolina *Hall*										x			x	
Camarotoechia dryope *Billings*	x													
Camarotoechia sappho ? *Hall*													x	
Camarotoechia tethys (*Billings*)			x									?	x	
Centronella glanfagea *Hall*		x	x							x		x	x	
Centronella tumida *Billings*	x													
Chonetes hemisphericus (*Hall*)			x						x	x	x	x	x	
Chonetes hudsonicus *Clarke*	x													
Chonetes mucronatus *Hall*		x	x				x						x	
Chonostrophia complanata *Hall*	x													
Chonostrophia reversa (*Whitfield*)													x	
Crania pulchella *Hall and Clarke*	x													
Crania sp.								x						
Cryptonella fausta ? *Clarke*	x													
Cyrtina biplicata *Hall*													x	
Cyrtina hamiltonensis *Hall*		x	x		x								x	
Cyrtina rostrata *Hall*	x													
Cyrtina varia *Clarke*	x													
Dalmanella lenticularis (*Vanuxem*)										x				
Delthyris raricosta *Conrad*		x												
Eatonia peculiaris *Conrad*	x													
Eatonia sinuata ? *Hall*	x													
Eunella harmonica *Hall*		x												
Eunella lincklæni *Hall*													x	
Hipparionyx proxima *Vanuxem*	x													
Leptæna rhomboidalis (*Wilckens*)	x	x	x					x	x	x	x		x	
Letostrophia oriskania *Clarke*	x													

List of Oriskany and Onondaga fossils.

	I			II					III		IV				V			VI		
Horizon	2-3	4	5	1	2	3	4	5	3	4	1	2	3	4	1	2	3	1	2	3
Megalanteris ovalis *Hall*	x																			
Meristella lata *Hall*	x																			
Meristella lentiformis *Clarke*	x																			
Meristella nasuta (*Conrad*)		x	x		x	x			x	x	x	x		x	x	x	x		x	x
Meristella walcotti *Hall and Clarke*	x																			
Metaplasia disparilis (*Hall*)					x															
Metaplasia pyxidata *Hall*	x																			
Nucleospira concinna *Hall*		x	x											x						
Nucleospira ventricosa *Hall*	x																			
Orbiculoidea sp.									x											
Oriskania navicella *Hall and Clarke*	x																			
Orthothetes deformis *Hall*	x																			
Orthothetes pandora (*Billings*)		x	x	x					x	x	x	x	x	x		x				
Pentamerella arata (*Conrad*)		x	x					x	x		x	x	x	x						
Pholidops arenaria *Hall*	x																			
Pholidops patina *Hall and Clarke*														x						
Pholidops terminalis *Hall*	x																			
Pholidostrophia iowaensis (*Owen*)			x								x			x						
Productella spinulicosta *Hall*								x												
Rensselæria cayuga *Hall and Clarke*	x																			
Rensselæria ovoides (*Eaton*)	x																			
Rensselæria ovulum *Hall and Clarke*	x																			
Reticularia fimbriata (*Conrad*)	x		x					x		x	x			x						
Rhipidomella cleobis (*Hall*)									?	x			x							
Rhipidomella livia (*Billings*)			x								x					x				

Rhipidomella musculosa *Hall*	x														
Rhipidomella oblata *Hall*	x														
Rhipidomella penelope ? *Hall*												x			
Rhipidomella semele *Hall*												x			
Rhipidomella vanuxemi *Hall*		x	x			x			x	x	x	x		x	
Schizophoria propinque *Hall*									x						
Spirifer acuminatus (*Conrad*)											x				
Spirifer arenosus (*Conrad*)	x														
Spirifer divaricatus *Hall*						x	x		x	x	x	x			
Spirifer duodenarius (*Hall*)		x	x	x		x	x	x	x	x	?	x			
Spirifer gregarius (*Clapp*)					x										
Spirifer macrothyris *Hall*							x		x	x					
Spirifer macrus *Hall*				x										?	
Spirifer murchisoni *Castelnau*	x														
Spirifer plicatus *Weller*	x														
Spirifer saffordi *Hall*	x														
Spirifer tribulis *Hall*	x														
Spirifer (arenosus) unicus *Hall*										x					
Spirifer varicosus *Hall*			x												
Spirifer sp.															x
Stropheodonta callosa ? *Hall*	x														
Stropheodonta concava *Hall*												x			
Stropheodonta demissa (*Conrad*)		x	x	x		x		x	x	x	x	x	x	x	x
Stropheodonta hemispherica *Hall*			x			x	x	x	x	x	x	x			
Stropheodonta inequiradiata *Hall*		x					x					x			
Stropheodonta inequistriata (*Conrad*)			x									x			
Stropheodonta lincklaeni *Hall*	x														
Stropheodonta magnifica *Hall*	x														
Stropheodonta magniventer *Hall*	x														
Stropheodonta patersoni *Hall*						x									
Stropheodonta perplana (*Conrad*)			x					x	x		x	x			
Stropheodonta vascularia *Hall*	x														
Strophonella ampla *Hall*	x	x	x	x			x	x	x	x	x	x	x	x	x

List of Oriskany and Onondaga fossils.

	I			II					III		IV				V			VI		
Horizon	2-3	4	5	1	2	3	4	5	3	4	1	2	3	4	1	2	3	1	2	3
Uncinulus mutabilis *Hall*	x																			
Actinopteria textilis arenaria (*Hall*)	x																			
Aviculopecten princeps ? (*Conrad*)														x						
Conocardium cuneus (*Conrad*)		x	x		x					x	x	x	x	x		x				
Cypricardinia indenta *Conrad*			x																	
Cypricardinia lamellosa *Hall*	x																			
Goniophora cerusus ? *Clarle*	x																			
Megambonia lamellosa *Hall*	x																			
Pterinopecten plumilus *Clarke*	x																			
Callonema lichas ? *Hall*														x						
Cyrtolites expansus *Hall*	x																			
Diaphorostoma desmatum *Clarke*	x																			
Diaphorostoma lineatum (*Conrad*)		x	x							x					x	x				
Diaphorostoma turbinatum (*Hall*)			x																	
Diaphorostoma unisulcatum (*Conrad*)			x																	
Diaphorostoma ventricosum (*Conrad*)	x																			
Loxonema pexatum *Hall*														x						
Platyceras ammon *Hall*																x				
Platyceras attenuatum *Hall*											x	x		x						
Platyceras bucculentum *Hall*											x									
Platyceras carinatum *Hall*		x												x						
Platyceras concavum *Hall*														x		x				
Platyceras conicum (*Hall*)			x								x			x						
Platyceras dentalium *Hall*			x								x	x								
Platyceras dumosum (*Conrad*)											x					?	x			

Platyceras erectum *Hall*													x	x
Platyceras nodosum *Conrad*	x													
Platyceras rictum *Hall*													x	
Platyceras undatum *Hall*									x					
Platyceras sp.				x										
Pleurorema lucina *Hall*											x			
Pleurotomaria delicatula *Hall*			x											
Straparollus clymenoides (*Hall*)			x											
Strophostylus matheri *Hall*	x													
Tentaculites elongatus *Hall*	x													
Tentaculites scalariformis *Hall*								x	x		x			
Gomphoceras eximium *Hall*								x						
Gyroceras sp.												x	x	
Orthoceras sp.								x			x		x	
Beyrichia sp.	x													
Chasmops anchiops (*Green*)	x		x					x	x		x			
Coronura diurus (*Green*)											x			
Hausmania phacoptyx *Hall and Clarke*	x	x	x	x		x	x	x	x		x			
Hausmania pleuroptyx (*Green*)	x													
Phacops correlator *Clarke*	x													
Phacops cristata *Hall*		x	x		x		x	x	x	x	x	x		
Phacops logani *Hall*	x													
Phacops rana (*Green*)			x	x									x	
Prœtus conradi *Hall*	x													
Prœtus crassimarginatus *Hall*			x					x		x	x			
Prœtus rowi (*Green*)			x			x		x			x			
Synphoria stemmatus *Clarke*	x													
Antodetus beecheri *Clarke*	x													

LOG OF WELL AT PETROLIA.

The railway journey from Hagersville to Thedford presents little of geological interest. The whole district is so heavily covered with drift that rock exposures are seen in but few places and only where streams have denuded the mantle of drift. The Onondaga-Hamilton contact is probably situated in the vicinity of London. East of Sarnia and a short distance south of the railway between London and Sarnia, is the centre of the oil district in Ontario at the town of Petrolia. The surface rock is Hamilton yielding the characteristic species of that formation in some abundance. A deep well drilled in the Petrolia oil field gave the following log:—

— —	Thickness.		Depth.	
	Ft.	M.	Ft.	M.
Hamilton.				
Blue shale	90	27·36	90	27·36
Shale and limestone	240	72·96	330	100·32
Onondaga				
Limestones (oil horizon)	190	37·76	520	158·08
Monroe?				
Banded grey, brown and black dolomites	690	209·76	1210	367·84
Salina				
Salt	65	19·76	1,275	387·60
Dolomite	20	6·08	1,295	393·68
Salt and dolomite	140	42·56	1,435	436·24
Dolomite	30	9·12	1,465	445·36
Salt	90	27·36	1,555	472·72
Salt and dolomite	50	15·20	1,605	487·92
Salt	25	7·6	1,630	495·52
Grey dolomite	10	3·04	1,640	498·56
Salt	67	20·36	1,707	518·92
Dolomite and salt	40	12·16	1,747	531·08
Salt	138	41·95	1,885	573·04
Dolomite, limestone and grey shales	130	39·52	2,015	612·56
Salt	90	27·36	2,105	639·92
Guelph and Niagara				
Dolomites	275	83·6	2,380	723·52
Cataract (?)				
Red and dark shales	60	18·24	2,440	741·76
Limestones	90	27·36	2,530	769·12
Richmond (Queenston)				
Red shales	275	83·6	2,805	852·72

—	Thickness.		Depth.	
	Ft.	M.	Ft.	M.
Richmond and Lorraine				
Grey shales and limestone .	205	62·32	3,010	915·04
Collingwood and Utica				
Dark shales..............	165	50·16	3,175	965·20
Trenton and Black River				
Limestones, etc...........	170	51·68	3,345	1016·88
Lowville (?)				
Limestones...............	115	34·96	3,460	1051·84
Chazy				
Shale and limestone.......	317	96·37	3,777	1148·20

THE HAMILTON FORMATION AT THEDFORD AND VICINITY.

BY

M. Y. Williams.

INTRODUCTION.

The villages of Thedford and Arkona are situated in the midst of an excellent farming and fruit growing region. For the most part the land is level, important variations occurring only along the drainage channels. The physiographic features about Thedford are directly related to the underlying formation which lies nearly horizontal. The Aux Sables river has entrenched its course 60 feet (18 m.) or more below the land surface. The stream bed, though fairly well graded, has not developed meanders. The secondary drainage channels are for the most part youthful and descend over falls of considerable height at a distance of 20 rods (100 m.) or more from their confluence with the river. Interstream mounds and rolling hills are occasionally present. The subsoil of the country consists in most places of unsorted gravel of local origin. Much of this gravel was formed on the shores of post-glacial lakes, the strand lines of which are close together at this point. Three distinct beaches are recognized in the vicinity, the Ridgeway, the Arkona and the Forest.

Some of the pebbles are of firm limestone and are fairly smooth as though having suffered wear from wave action, but fossils are frequently found in the gravels from which the surface markings are scarcely removed.

The only Palæozoic formation exposed at Thedford is the *Hamilton*, which is estimated to be about 300 feet (91 m.) thick. The characteristic rocks are blue-grey clay shale and interbedded calcareous shale and limestone. Fossils are very abundant and are found in a remarkably good state of preservation.

Fossils of the Hamilton Formation.

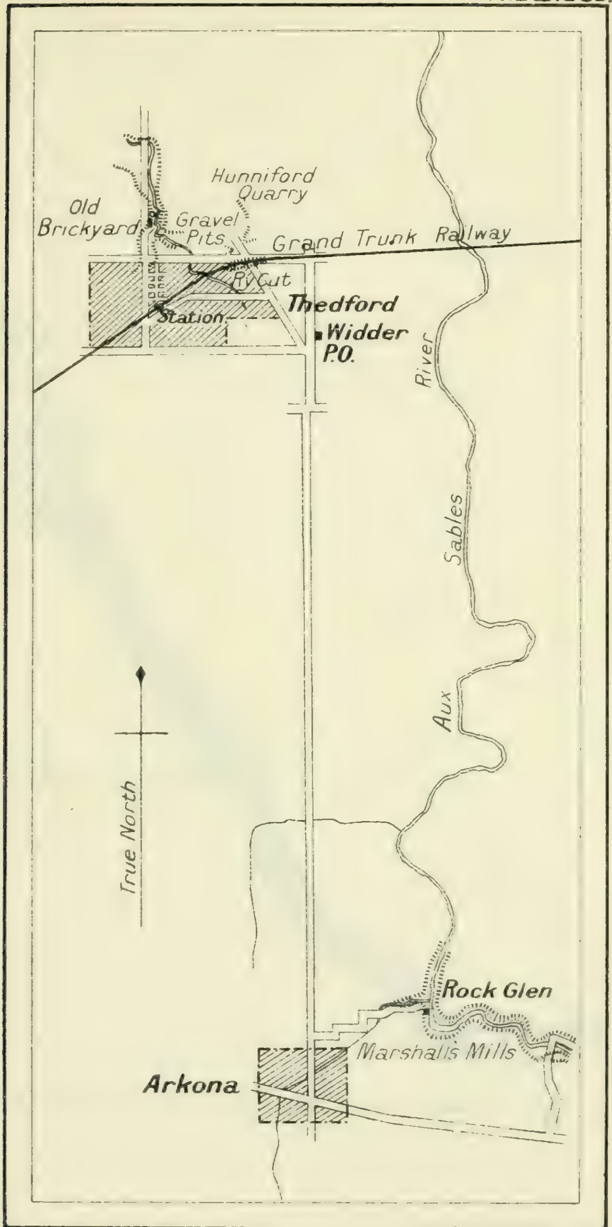
The different strata exposed in the Thedford region are indicated in the accompanying columnar section which has been compiled from the various outcrops in the district.

About 80 feet (24 m.) of Hamilton shales and limestones are exposed in the vicinity of Thedford and along the banks of the Aux Sables river. The shales which make up most of the thickness weather down into fine blue clay. The limestones are blue-grey in colour and are generally firm and resistant. The section is divided into a lower series of shales and an upper series of mixed limestone and shales.

1—The lower shales are not highly fossiliferous except in a few beds. The fauna characterizing them includes:—

Arthroacantha punctobranchiata *Williams*
Chonetes scitula *Hall*
Schuchertella arctostiatus (*Hall*)
Spirifer mucronatus arkonensis *Shimer and Grabau*
Stropheodonta demissa (*Conrod*)
Tentaculites attenuatus *Hall*
Platyceras buccultentum *Hall*
Bactrites obliqueseptatus arkonense *Whiteaves*
Tornoceras uniangularis (*Conrad*)
Phacops rana (*Green*)

2—At the base of the upper division is a four-inch bed of limestone succeeded by six inches of black carbonaceous shale. This black shale is very persistent and always contains many compressed specimens of *Leiorhynchus laura* (Billings) along with *Styliolina fissurella* (Hall).



Geological Survey, Canada

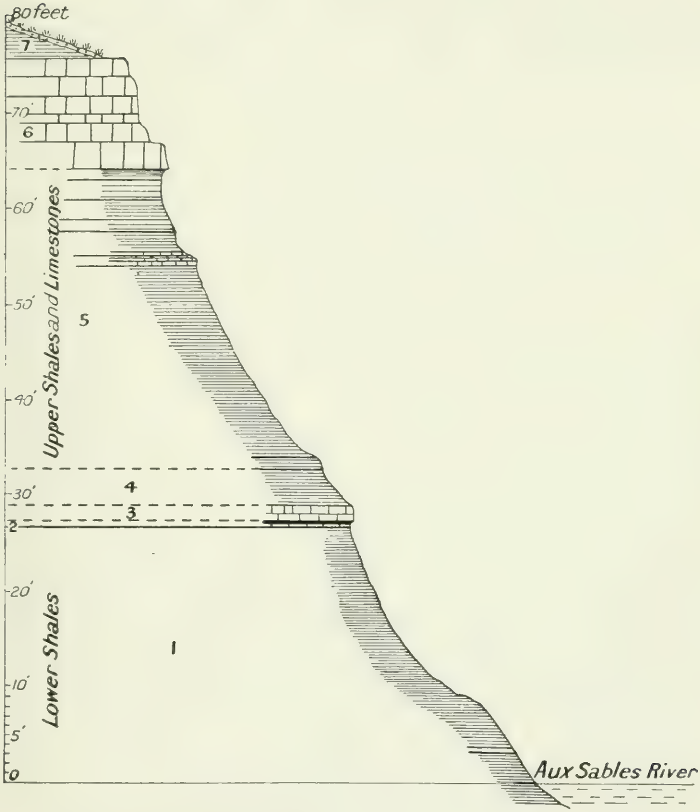
Route map between **Thedford** and **Arkona**

Miles

1 0 1 2 3

Kilometres

1 0 1 2 3 4 5



Composite section of Hamilton formation (Devonian) at Thedford, Ontario.

3—This limestone is referred to as the 'encrinal limestone.' Some of the common fossils are:—

Craspedophyllum archiaci (*Billings*)
Favosites turbinata *Billings*
Leiorhynchus laura (*Billings*)

4—This shale possesses a rich coral fauna with *Heliophyllum* and *Cystiphyllum* predominating. The more common fossils are:—

Corals—
Alveolites goldfussi *Billings*
Cladopora frondosa (*Nicholson*)
Cyathophyllum conatum *Hall*
Cystiphyllum vesiculosum (*Goldfuss*)
Favosites billingsi *Rominger*
Favosites placenta *Rominger*
Heliophyllum halli *E. and H.*
Phillipsastrea verneuili *E. and H.*
Striatopora linnaeana *Billings*
Zaphrentis prolifica *Billings*
Bryozoans—
Fenestella arkonensis *Whiteaves*
Brachiopods—
Athyris fultonensis (*Swallow*)
Camarotoechia thedfordensis *Whiteaves*
Chonetes lepida *Hall*
Cyrtina hamiltonensis *Hall*
Pholidostrophia iowaensis (*Owen*)
Rhipidomella penelope (*Hall.*)
Spirifer mucronatus thedfordensis *Shimer and Grabau*
Worms—
Spirorbis omphalodes (*Goldfuss*) *Nicholson*
Gastropods—
Platyceras subspinosum *Hall*
Trilobites—
Phacops rana (*Green*)

5—The shales and argillaceous limestones of this member contain comparatively few fossils. *Spirifer mucronatus thedfordensis* S. and G., occurs, increasing in abundance towards the top. *Chonetes lepida* Hall, *C. vicina* (Castlenau), *Pterinea flabellum* (Conrad), *Phacops rana* (Green), *Cryphaeus boothii* (Green), occur in the lower beds.

6—This limestone consists of heavy beds separated by shale partings. Some of the characteristic fossils are:—

Ceratopora intermedia (*Nicholson*)
Athyris fultonensis (*Swallow*)
Leiorhynchus laura (*Billings*)
Spirifer mucronatus thedfordensis *S. and G.*
Stropheodonta concava (*Hall*)

7.— This shale is poorly exposed at the top of the formation and appears to be nearly barren of fossils.

Sections of the Hamilton Formation.

The best localities for the examination of the strata and for the collecting of fossils are as follows:—

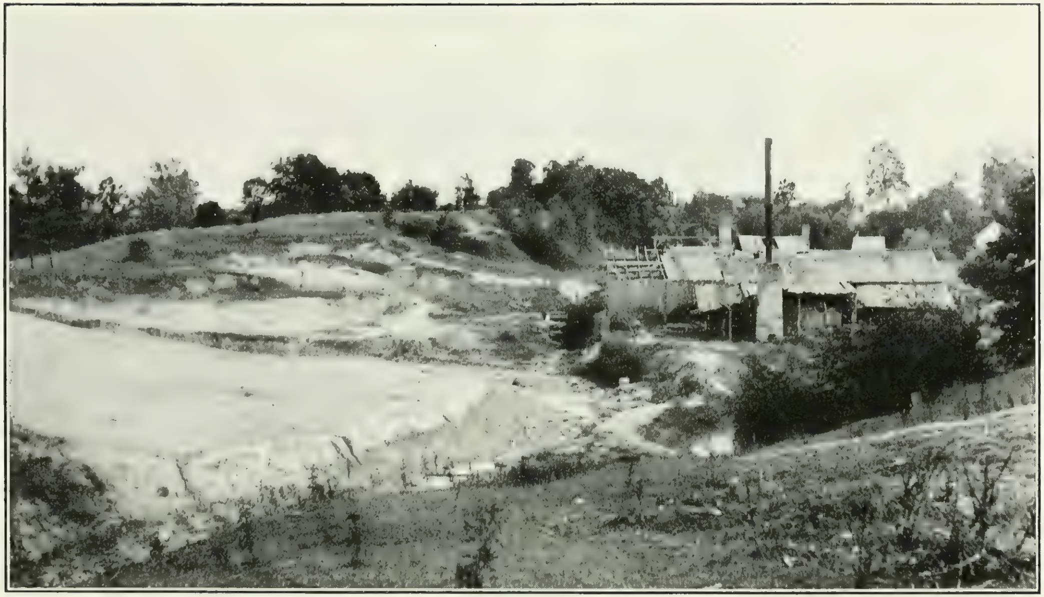
1.—Railway cut, one mile east of Thedford.
2.—Gravel pits and Hunniford's fields north of cut.
3.—The brick yards.
4.—The valley of the Aux Sables river between Rock Glen and Marshall's mills.

Railway cut east of Thedford.—Fossils may be collected from both sides of the railway cut east of Thedford, but the best section is exposed on the south side. The exposure here extends 25 feet (7·6 m.) above the road bed, and consists of limestone and shale representing the upper 15 or 16 feet (4·5 or 4·8 m.) of zone No. 5 and the lower 9 or 10 feet (2·7 or 3 m.) of zone No. 6. The lowest beds of all are obscured, but crinoid remains were formerly obtained from them. The fossils already listed for zones 5 and 6 occur in abundance particularly *Spirifer mucronatus thedfordensis* S. and G., in the lower 10 feet (3 m.).

Gravel Pits and Quarries north of the Railway cut.—A short distance north of the railway cut, a shallow pit in the overlying gravel has exposed the upper layers of the section seen in the cut.

The more common fossils at this point are:—

Pentremites sp.
Athyris fultonensis (*Swallow*)
Cyrtina hamiltonensis *Hall*
Eunella sp.
Meristella sp.
Pholidostrophia iowaensis (*Owen*)
Stropheodonta demissa (*Conrad*)
Platyceras sp.
Phacops rana (*Green*)



Exposure of Hamilton shale at the brickyard, Thedford, Ont.

2.—Northward from the above locality several shallow quarries were opened in the fields for the production of stone from the encrinal layer (No. 3). These shallow pits, long since abandoned, have proved a rich collecting ground for the corals of the overlying shale. This locality has also yielded many examples of the rarer blastoids for which the Thedford section is noted, e.g. *Eleutherocrinus cassedayi* Shumard and Yandell, *Codaster canadensis* Billings, and *Nucleocrinus elegans* Conrad.

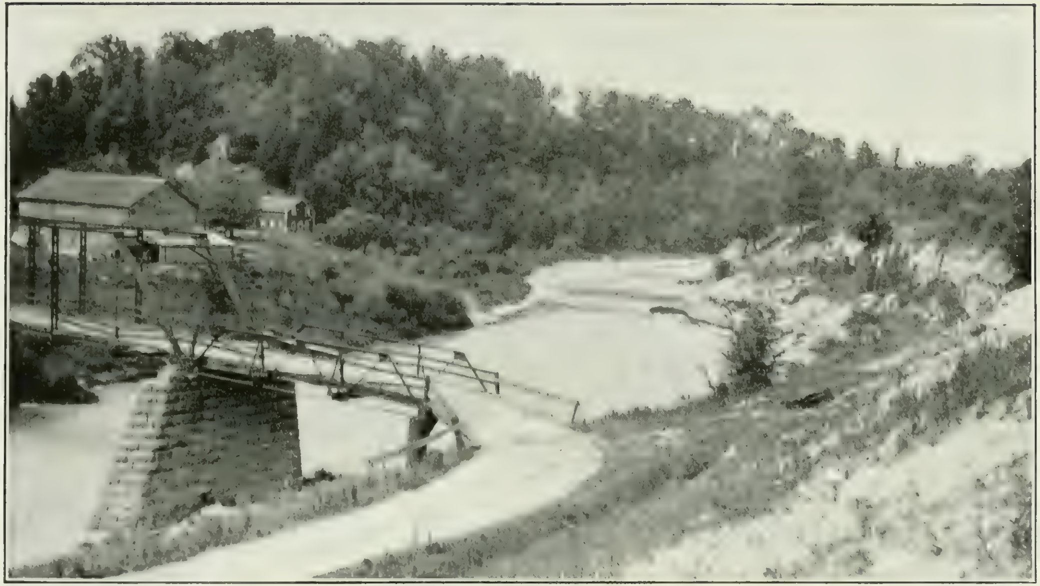
3. Hamilton Section at the Brickyard. — The exposed clay surfaces at the brickyard afford excellent collecting ground. Upstream near the first important bend, the black *Leiorhynchus* shale (No. 2), at the base of the upper shale division is about 14 feet (4·2 m.) above the creek bed. The coral shales are the highest strata exposed and from them come most of the fossils that make the brickyard a noted collecting ground for numerous species of Hamilton corals. Abundant and well preserved examples of the various species of *Heliophyllum*, *Cystiphyllum*, *Favosites*, *Acervularia*, etc., may be found here. Many of the other fossils of zones 1, 2, 3 and 4 may also be obtained.

Good exposures with excellent collecting are to be found farther down stream where the spring freshets have cut gullies in the soft strata of zone No. 4. The interesting coral, *Microcyclus discus* Meek and Worthen, occurs at this horizon associated with *Ancyrocrinus* and an occasional *Pentremites*.

4. Hamilton Section of the Aux Sables River.— An excellent section exposing the strata from near the base of zone No. 1 to the top of zone No. 6 extends up the branch stream which enters the Aux Sables river a short distance below the power house (Power glen or Rock glen). The difference in elevation between the mouth of the stream and the top of the limestone above the falls is 66 feet (10 m.).

About 100 yards (91 m.) below the falls, right at the waters edge, is a thin bed of dark argillaceous limestone containing species of *Platyceras* associated with *Arthroacantha* fragments. Small examples of *Schuchertella* are also present. About 29 feet (8·8 m.) above the mouth of the brook, the six inch bed of black shale occurs, marking the top of the lower shale division (See No. 2 of section). *Leiorhynchus laura* is plentiful in this layer. The limestone immediately above furnishes the fossils common in

Falls over Hamilton strata in Rock Glen near Arkona, Ontario.



Marshall's Mills, Aux Sables river, Ontario.

the encrinal limestone (No. 3): it is succeeded by the coralline shales. The overlying shales are not very fossiliferous, but at the top of the falls the heavy bedded limestone carries the fossils characteristic of zone No. 6.

In the river bed below Rock glen, many fine corals of the genera *Heliophyllum*, *Zaphrentis* and *Favosites* are found in association with numerous bryozoans and an occasional trilobite.

At a bend in the river, about ·4 miles (·6 km.) below the bridge at Marshall's mills, a section about 75 feet (22·8 m.) thick is exposed. The top of the lower shales and the bed containing *Leiorhynchus laura* are situated about 27 feet (8·2 m.) above the water. The upper shales are somewhat obscured here by the loose material, and the thick upper limestones are poorly exposed. The characteristic fossils of the coral shale are very plentiful in the débris scattered along the river. The most satisfactory collecting ground is just below the steel bridge near where Marshall's mills used to stand. The section here includes about 27 feet (8·2 m.) of the lower shales succeeded by about 22 feet (6·7 m.) of limestone and shale, all capped by about 4 feet (1·2 m.) of gravel. The best collecting is from the river up to the second firm bed, five feet (1·5 m.) above the *Leiorhynchus* shale (No. 2). Fossils of zones 1, 2, 3 and 4 are very plentiful in this locality. Besides the numerous species of corals, bryozoans and brachiopods, *Tornoceras uniangulare* (Conrad), *Bactrites obliqueseptatus arkonense* Whiteaves, *Pentremites*, etc., are likely to be found. Some of the rarer fossils to be obtained here are:—*Microcyclus discus* Meek and Worthen, *Cladopora* cf. *fischeri* (Billings), *Trachypora elegantula* (Billings), *Nucleocrinus elegans* (Conrad), *Camarotoechia thedfordensis* Whiteaves, *Cyrtina hamiltonensis* (Hall) and, *Phacops rana* (Green).

ANNOTATED GUIDE.—*Continued.*

Miles and Kilometres.	
	The country is very flat to the eastward of Thedford, with little of geological interest to be observed until the Thames river is crossed at St. Marys. Salt wells were formerly operated near Park Hill.
38·49 m. 61·9 km.	**St. Marys**—Alt. 1,082 ft. (38·49 m.). Although no rock exposure is to be seen from the train,

Section of the Hamilton formation near Marshall's Mills, Aux Sables river, Ontario.

Miles and Kilometres.

the underlying Onondaga strata are comparatively near the surface and have been worked in several quarries, besides presenting natural exposures along the Thames river. The Onondaga strata at this point are less coralline, but richer in other forms than at Hagersville. Among the more common species are the following:—

Favosites hemispherica *E. and H.*
Streptelasma prolificum (*Billings*)
Atrypa reticularis (*Linnæus*)
Chonetes hemisphericus *Hall*
Leptæna rhomboidalis (*Wilckens*)
Martinia maia (*Billings*)
Meristella nasuta (*Conrad*)
Spirifer duodenarius (*Hall*)
Spirifer gregarius *Clapp*
Stropheodonta demissa (*Conrad*)
Stropheodonta inequistriata (*Conrad*)
Strophonella ampla *Hall*

Aviculopecten princeps (*Conrad*)
Concardium cuneus (*Conrad*)
Panenka grandis *Whiteaves*
Vanuxemia tomkinsi *Billings*
Paracyclas elliptica *Hall*
Platyceras ventricosum (*Conrad*)

Cyrtoceras sp.
Gomphoceras eximium *Hall*
Gyroceras cyclops *Hall*
Nautilus sp.
Orthoceras sp.
Macropetalichthys sullivanti *Newberry*.

48·5 m. 78 km. **Stratford**—Alt. 1,188·8 ft. (48·51 m.). This city, which is an important railway and manufacturing centre, is situated nearly on the summit between Toronto and Sarnia. The drift at this point is heavy, reaching a thickness of 143 feet (43·6 m.). From Stratford to Guelph the country is rolling and of morainic character, with occasional gravel bars of post-glacial origin.

Miles and Kilometres.

88·3 m.
142·1 km.

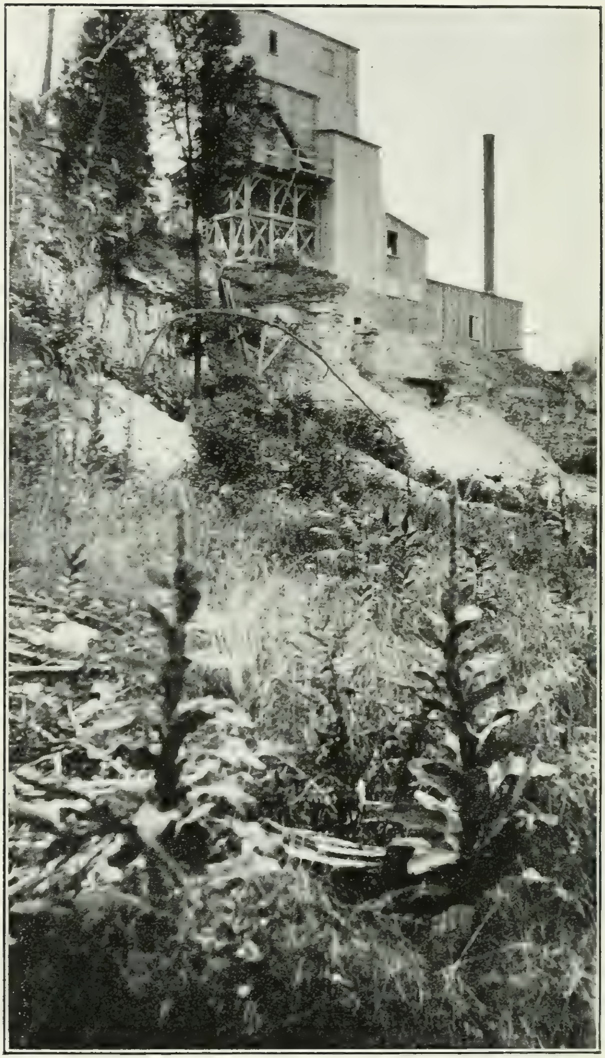
Guelph—Alt. 1,067 ft. (88·3 m.). The uppermost layers of the Niagara may be seen near Guelph, while the characteristic dolomites of the Guelph formation are exposed at several points between Guelph and Galt.

At Kennedy's quarry and limekiln (A) near Guelph, about 30 feet (9·1 m.) of typical Guelph dolomite is exposed in fairly heavy beds. Stromatoporoids and fragmentary corals are the common fossils, but the locality is not a good one for collecting. On the other hand, it presents an interesting dome-like structure in the strata.

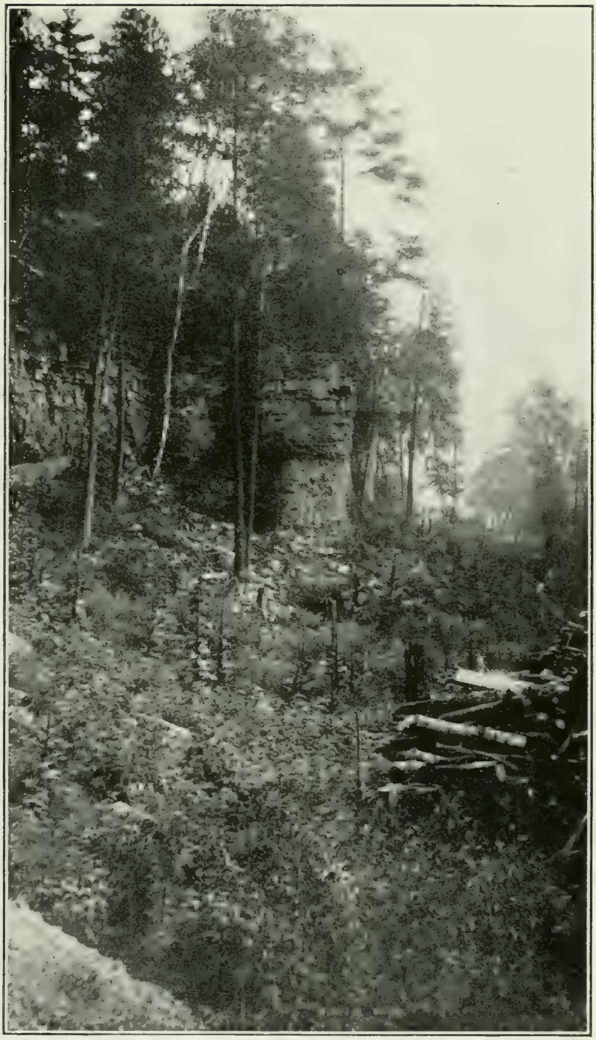
At MacFarlane's tavern (B) 14 feet (4·2m.) of thin bedded bituminous limestone of the upper Niagara is exposed. The rock is hard and black, with galena, zinc blende and bitumen in vugs. The fossils consist chiefly of casts, which are difficult to identify. In the lower beds a small form resembling *Whitfieldella nitida* Hall is common. Five feet (1·5 m.) from the bottom is a six-inch zone containing numerous gastropods related to *Trochonema pauper* Hall, and *Straparollus hippolyta* Billings. Higher up are found *Favosites niagarensis* Hall, and a branching coral resembling *Cladopora multipora* Hall. On the same side of the road, farther east and at a slightly higher level, undoubted Guelph strata are seen, with *Halysites catenulatus* Linn, and *Pycnostylus guelphensis* Whiteaves.

Good exposures are presented in the scarped bank of the Eromosa river on the Prison farm (C, D, E). The section is interesting rather from a stratigraphic than from a palæontological viewpoint. In the building-stone quarry the following beds may be recognized in descending order:—

	Thickness. Feet.	Metres.
Guelph—		
Thin-bedded dolomites..........	6	1·8
Thick-bedded, compact dolomites suitable for building stone.....	7	2·1
Thin-bedded dolomites..........	6	1·8



Base of Niagara-Guelph transition beds. Prison Farm, Guelph, Ont.



Niagara-Guelph transition beds with typical Guelph strata at the top.
Prison Farm, Guelph, Ont.

	Thickness. Feet.	Metres.
Niagara—		
Dark, thin-bedded bituminous dolomites	6	1·8

The upper beds alone are fossiliferous, with a predominance of corals, *e.g. Favosites niagarensis* Hall, *Heliophyllum* sp., and *Halysites catenulatus* Linn. Indeterminable stromatoporoids are also present in some abundance. Of the Guelph gastropods, *Cœlocaulus bivittatus* Hall, is the most common; farther southward the underlying Niagara beds increase in relative thickness.

Robert Kennedy's quarry (F) situated on Waterloo avenue, shows a good exposure of about 25 feet (7·6 m.) of irregularly bedded, light coloured dolomite. The common fossils are:—

Favosites niagarensis *Hall*
Halysites compacta *Rominger*
Conchidium occidentale (*Hall*)
Trimerella grandis *Billings*.

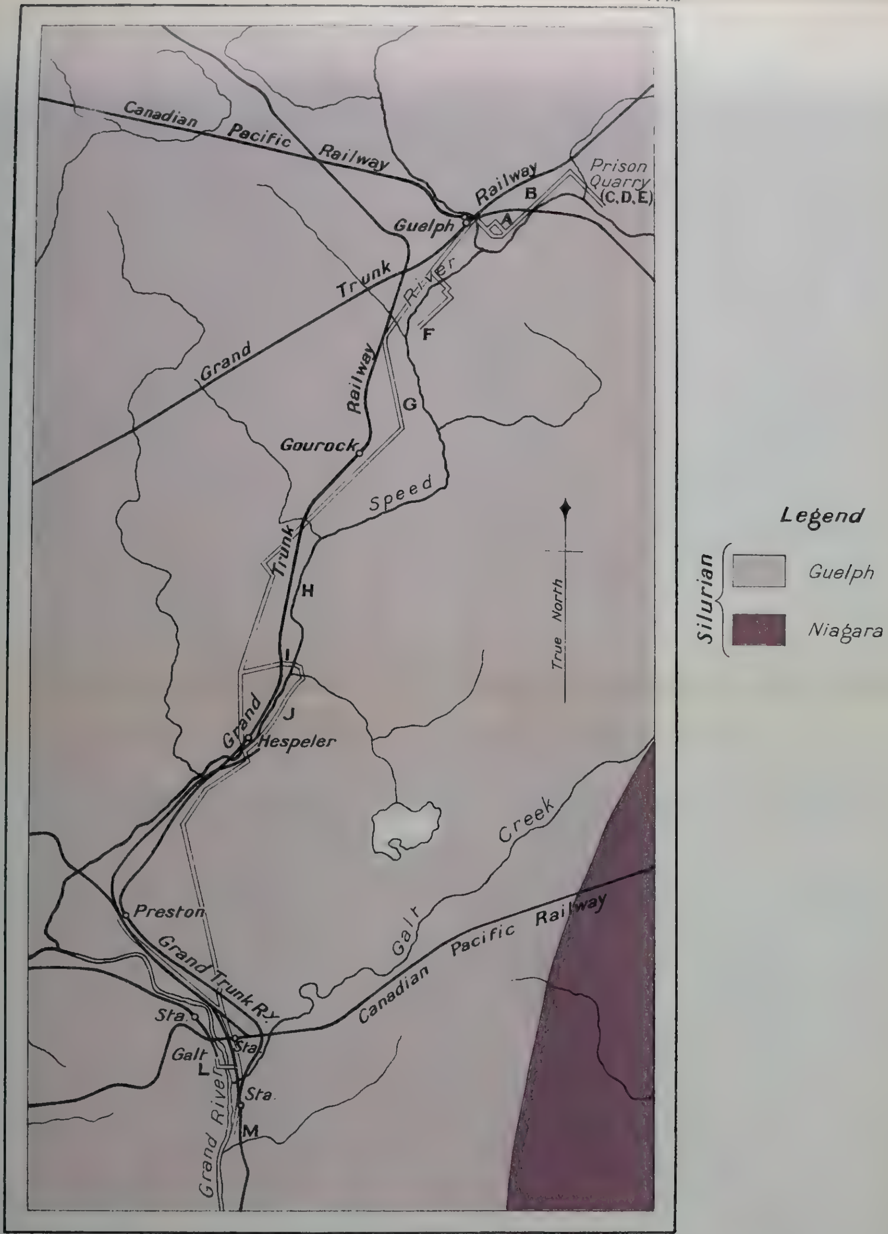
The large quarry of the Standard White Lime Company is situated in more fossiliferous strata than the other excavations near Guelph. On entering at the southwest angle, many corals are seen in a distinct reef, including:—

Favosites niagarensis *Hall*
Pycnostylus guelphensis *Whiteaves*
Halsyites catenulatus *Linn*
Zaphrentis cf. racinensis *Whitfield*

Higher up and a little farther east, the above corals are to be seen associated with numerous stromatoporoids; the latter are nearly all indeterminable, but the following species are the more common:—

Stromatopora galtensis (*Dawson*)
Stromatoporella elora *Parks*
Clathrodictyon striatellum (*D'Orb*).

The remainder of the fauna consists largely of brachiopods and gastropods, with a small number of cephalopods. The more important



Geological Survey, Canada

Route map between Guelph and Galt

Miles

1 0 2 4 6

Kilometres

1 0 2 4 6 8

species are given in table No. 1 on page 118. At the north end of the quarry a few examples of *Megalomus* are found, but this characteristic genus is not prolific near Guelph.

The débris thrown from the shallow cuts along the Grand Trunk railway north of Hespeler affords one of the richest and most accessible collecting grounds in the district. The common species are given in column No. 2 of the table on page 118.

Excellent exposures occur on both sides of the river above and below Galt. A typical section is seen in the Dickson Park quarry, where *Megalomus canadensis* occurs in great abundance associated with the species given in the third column of the table.

The quarries of Christie and Henderson, beyond Galt, present a face of about 45 feet (13·7 m.) of both thin and thick-bedded stone characterized throughout by a wonderful profusion of *Megalomus canadensis.* The species given in the fourth column of the accompanying table are common in this quarry.

	1 Standard White Lime Company's Quarry, Guelph.	2 Grand Trunk Railway, cut north of Hespeler.	3 Dickson Park Quarry, Galt.	4 Christie and Henderson Quarry, Galt.
Stromatoporoids—				
Clathrodictyon striatellum (*D'Orb.*)	x			
Stromatopora galtensis (*Dawson*)	x			
Stromatoporella elora *Parks*	x			
Corals—				
Favosites niagarensis *Hall*	x	x		x
Favosites hisingeri *E and H.*		x		x
Halysites compacta *Rominger*		x		
Halysites catenulatus *Linn.*	x	x		
Pycnostylus elegans *Whiteaves*		x		
Pycnostylus guelphensis *Whiteaves*	x	x		
Zaphrentis racinensis *Whitfield*	x	?		
Brachiopods—				
Conchidium occidentale (*Hall*)		x	x	x
Monomerella ovata *Whiteaves*	x	x	?	
Monomerella ovata lata *Whiteaves*		x		
Orthis sp.		x		
Rhinobolus galtensis (*Billings*)	x	x		
Spirifer crispus (*Hisinger*)	x	x		
Strophomena sp.		x		

Trimerella acuminata *Billings*		x		
Trimerella grandis *Billings*	x	x		
Whitfieldella hyale (*Billings*)	x	x		x
Branching Bryozoa indet.		x		
Gastropods—				
Bellerophon shelbiensis *Clarke and Ruedemann*		x		
Cœlocaulus bivittatus (*Hall*)		x		x
Cœlacaulus estella (*Billings*)		x	x	x
Cœlacaulus longispira (*Hall*)	x			
Cœlocaulus macrospira (*Hall*)	x	x	x	x
Cœlocaulus turritiformis (*Hall*)			x	
Eotomaria durhamensis (*Whiteaves*)		x		
Eotomaria galtensis (*Billings*)			x	
Euomphalopterus elora (*Billings*)		x		
Euomphalopterus valeria (*Billings*)		x		x
Euomphalus circinatus *Whiteaves*			x	
Euomphalus cf. fairchildi *C. and R.*		x		
Euomphalus galtensis *Whiteaves*			x	
Holopea gracia *Billings*		x		
Holopea guelphensis *Billings*		x		
Holopea harmonia *Billings*		x		
Hormotoma whiteavesii *Clark and Ruedeman*			x	x
Loxoplocus solutus (*Whiteaves*)	x		x	x
Murchisonia billingsana *Miller*		x		
Pleurotomaria viola *Billings*		x		x
Poleumita cf. crenulata (*Whiteaves*)	x			
Poleumita sulcata (*Hall*)		x	x	x
Pycnomphalus salaroides (*Hall*)		x		
Straparollina daphne *Billings*		x		
Trematonotus alpheus *Hall*	x	x		
Turritoma boylei (*Nicholson*)				x

	1 Standard White Lime Company's Quarry, Guelph.	2 Grand Trunk Railway, cut north of Hespeler	3 Dickson Park Quarry, Galt.	4 Christie and Henderson Quarry, Galt.
Pelecypods—				
Megalomus canadensis (*Hall*	x		x	x
Mytilarca acutirostrum *Hall*		x		
Cephalopods—				
Cyrtoceras arcticameratum *Hall*				x
Cyrtoceras orodes *Billings*	x			x
Kionoceras darwini (*Billings*)	x			
Orthoceras cf. abnorme *Hall*	x			
Phragmoceras hector *Billings*	x	x		x
Trilobites—				
Calymmene niagarensis *Hall*		x		
Ceraurus niagarensis *Hall*		x		

Miles and Kilometres.

98·56 m. 135 km. **Rockwood**—Alt. 1,182 ft. (370 m.). Eastward from Guelph, the Niagara limestones are exposed at several places. To the west of Rockwood the strata are thin, but east of that place the heavier dolomites are exposed. Fossils are not well preserved in these rocks but the following species are comparatively common:—

Favosites gothlandica *Lamarck*
Halysites catenulatus *Linnæus*
Rhynchotreta cuneata americana *Hall*
Spirifer niagarensis (*Conrad*)
Trematospira camura (*Hall*)
Fenestella *sp.*
Bellerophon *sp.*
Pterinea *sp.*
Cyrtoceras *sp.*
Orthoceras *sp.*

109·63 m. 175·4 km. **Limehouse**—Alt. 1,002 ft. (304·6 m.). The upper shales of the Cataract formation are exposed in the railway cut at Limehouse: above these, the lower members of the Niagara may be seen. North of this place the basal sandstone of the Cataract is exposed over a considerable area and finally passes under the other members in the face of the cuesta.

107·8 m. 172·5 km. **Georgetown**—Alt. 846 ft. (257 m.). The red shales of the Richmond formation are exposed in the river valley at Georgetown. No further rock exposures are seen before crossing the Humber river where the Lorraine shales are exposed.

136·89 m. 219·2 km. **Toronto**—Alt. 254 ft. (77·2 m.). On approaching the city, the post-glacial sands may be seen between Lambton and Parkdale.

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EXCURSION B3.

THE PALÆOZOIC SECTION AT HAMILTON, ONTARIO.

BY

WILLIAM A. PARKS.

CONTENTS.

INTRODUCTION.

The sharp escarpment (Niagara cuesta) which separates the upland of western Ontario from the lowland to the east extends from Queenston on the Niagara river to Hamilton at the head of Lake Ontario and thence northward into Bruce peninsula between Lake Huron and Georgian bay. As the difference in elevation between lowland and upland is about 350 feet (106 m.) excellent rock exposures are presented where the face of the escarpment is abrupt. The strata revealed in the southern part of the escarpment consist of the uppermost member of the Ordovician (Richmond) and the lower beds of the Silurian. Towards the north still lower Ordovician strata are exposed. The more favourable points for the study of sections are the following:—

Niagara gorge. (See Excursion B 1.)

Grimsby, half way between Niagara and Hamilton. (Present Excursion).

Hamilton, at the head of Lake Ontario. (Present Excursion).

Credit Forks, about 50 miles (80 km.)north of Toronto. (See Excursion B).

Collingwood, on Georgian bay. (See Excursion C 5).

A generalized section of the cuesta showing the actual strata is indicated in the central column of the accompanying table. The stratigraphic classification adopted in the latest publications of the State of New York is shown on the left. The right hand column presents a classification which has been recently proposed.

TABLE OF FORMATIONS.

Classification of New York State Geologists.				Strata exposed in Ontario.	Proposed Classification.		
Ontaric or Siluric	Niagaran	Lockport	Lockport	Dolomites and dolomitic cherts	Lockport	Niagara	Silurian
		Clinton	Rochester	Grey shales	Rochester		
			Clinton	Limestone and shales	Clinton	Clinton	
	Oswegan	Medina	Medina	Grey sandstones	Medina	Medina	
			Medina	Red sandstones and shales	Medina		Ordovician
			Medina	Shales and limestones	Cataract	Cataract	
			Whirlpool	Grey sandstones	Cataract		
			Queenston	Red shales	Queenston	Richmond	
	Oswego sandstone						

GENERAL DESCRIPTION OF FORMATIONS.

The Queenston formation consists essentially of red shales with an occasional green band. This formation is unfossiliferous in the Niagara and Hamilton sections, but in the Collingwood section, a distinct Richmond (Ordovician) fauna is revealed. It has therefore become necessary to separate the Queenston shale from the Medina formation in which it has been long included. The overlying grey sandstone (Whirlpool sandstone of Grabau) has hitherto been regarded as Medina, but it is now proposed to consider it as the basal member of a new formation-the Cataract—which represents an invasion from the north and west at the commencement of Silurian time. The upper limestones and shales of this formation are highly fossiliferous and present a fauna comparable with that of the Brassfield formation of Ohio and Kentucky.

In the Credit region, this basal sandstone has been confused with the upper or true Medina sandstone of the Niagara gorge; in consequence, the shales and limestones overlying it have been erroneously ascribed to the Clinton.

All the strata exposed in the Niagara gorge continue as far as Grimsby and even to Hamilton, but at the latter place, the Rochester shale, the Clinton and the Medina have become greatly reduced in thickness. At the Forks of the Credit, these formations have disappeared entirely and the Cataract formation has increased correspondingly. At Collingwood the Cataract formation is again decidedly thinner and presents a different petrographic aspect, consisting of limestone with some shale at the top.

The gradual decrease of thickness in the Rochester, Clinton and Medina strata, and the increase in the Cataract in passing northward is indicated in the following table:—

		Niagara.	Grimsby.	Stony Creek.	Hamilton.	Ancaster.	Credit Forks.	Collingwood.
		ft.	ft.	ft.	ft.	ft.	ft.	ft.
Niagara.	Lockport dolomite, cherts, etc.	150	12	13	22	....	30	75
"	Rochester shale	68	45	25	15	12	00	00
Clinton.	Limestones and shales.	32	14	13	12	12	00	00
Medina.	Grey band sandstone.	7½	25	14	12	11	00	00
"	Red sandstones, etc.	50						
Cataract.	Shales and limestones.	26	74	79	80	??	95	55
"	Sandstone	25	6	6	10	??	16½	00

Richmond. Red shales of great thickness, extending far below the section, except at Collingwood.

Rochester shale and Lockport dolomite between the two falls on Forty Mile creek, Grimsby, Ontario.

DETAILED DESCRIPTION OF SECTIONS.

For a general description of the geology along the line of the railway between Toronto and Hamilton see the guide book for Excursion A 12.

From Hamilton to Grimsby, the railway traverses a fertile plain underlain by the red shales of the Queenston formation (Ordovician). This region forms part of a celebrated belt of fruit lands extending from the Niagara river to Hamilton.

Section at Grimsby.

The valley of Forty Mile creek at Grimsby presents one of the best sections to be seen along the face of the cuesta.

The following table indicates in descending order the thickness of the various layers:—

	Thickness.		Elevation.	
	Feet.	Metres.	Feet.	Metres.
1—Lockport dolomite.......	12	3·6	576	175
2—Rochester shale...........	45	13·7	564	171·4
3—Clinton thick bed.........	4	1·2	519	157·7
4—Clinton thin beds with	10	3·0	515	156·5
5—Pentamerus zone at the base				
6—Medina grey band........	5	1·5	505	153·5
7—Medina mottled sandstone and shale..................	20	6·0	500	152·0
8—Cataract shale and limestone.....................	74	22·6	480	146·0
9—Basal Cataract sandstone..	6	1·8	406	123·4
10—Red Richmond shales....			400	121·6
Grimsby station...			287	87·2

1. Lockport Dolomite.— The Lockport dolomite, as exposed near the head of the ravine at Grimsby, consists of heavy-bedded stone; but on the sides of the ravine, nearer the face of the cuesta, a thin-bedded transition zone of about eight feet (2·4 m.) occurs between it and the Rochester shale. The dolomite is not highly fossiliferous at this point but it nevertheless yields some characteristic Niagara species. Brachiopods are by far the most abundant organisms: the following species may be obtained:—

Atrypa reticularis (*Linn.*)
Atrypa nodostriata *Hall*
Camarotoechia neglecta (*Hall*)

Leptaena rhomboidalis (*Wilckens*)
Rhynchotreta cuneata americana *Hall*
Spirifer crispus (*Hisinger*)
Spirifer niagarensis (*Conrad*)
Spirifer radiatus *Sowerby*
Trematospira camura (*Hall*)
Whitfieldella nitida *Hall*
Whitfieldella nitida oblata *Hall*

Brow of the Niagara cuesta, showing Lockport dolomite, Hamilton, Ontario.

2. Rochester Shale.—The lower and more shaly beds of the Rochester shale are rich in fossils among which brachiopods and, more particularly, bryozoans abound. These beds are also noted for rare cystids and crinoids, although with the exception of *Caryocrinus ornatus* and *Stephanocrinus angulatus*, these remarkable forms are but seldom encountered. The following list contains the more common species from these beds:—

Corals—
    Enterolasma caliculus (*Hall*)
    Favosites cf. parisiticus cf. niagarensis *Hall*
Hydrozoans—
    Dictyonema retiforme *Hall*
Crinoids—
    Eucalyptocrinus coelatus (*Hall*)
    Herpetocrinus brachiatus (*Hall*)

Crinoids—*Con.*
- Herpetocrinus convolutus (*Hall*)
- Homocrinus cylindricus *Hall*
- Ichthyocrinus laevis *Conrad*
- Lecanocrinus macropetalus *Hall*
- Lyriocrinus dactylus (*Hall*)
- Periechocrinus speciosus *Hall*
- Stephanocrinus angulatus *Conrad*
- Thysanocrinus liliiformis *Hall*

Cystids—
- Apicoystites elegans *Hall*
- Callocystites canadensis, *Billings*
- Callocystites jewetti *Hall*
- Caryocrinus ornatus *Say*
- Gomphocystites tenax *Hall*
- Holocystites globosus *Miller*

Asteroids—
- Squamaster echinatus *Ringueberg*
- Palæaster niagarensis *Hall*
- Protaster stellifer *Ringueberg*

Brachiopods—
- Atrypa reticularis (*Linn*)
- Atrypa rugosa (*Hall.*)
- Camarotoechia neglecta (*Hall*)
- Camarotoechia obtusiplicata (*Hall*)
- Dalmanella elegantula (*Dalman*)
- Delthyris sulcata *Hisinger*
- Homœospira apriniformis (*Hall*)
- Leptæna rhomboidalis (*Wilckens*)
- Lingula lamellata *Hall*
- Orthis flabellites *Foerste*
- Plectambonites transversalis (*Wahlenberg*)
- Rhipidomella hybrida (*Sowerby*)
- Rhynchonella robusta *Hall*
- Schuchertella subplana (*Conrad*)
- Spirifer niagarensis (*Conrad*)
- Spirifer radiatus *Sowerby*
- Whitfieldella nitida *Hall*
- Whitfieldella nitida oblata *Hall*

Bryozoans—
- Acanthoclema asperum (*Hall*)
- Batostomella granulifera (*Hall*)
- Bythopora spinulosa (*Hall*)
- Callopora elegantula *Hall*

Bryozoans—*Con.*

Chilotrypa ostiolata (*Hall*)
Diamesopora dichotoma *Hall*
Diploclema sparsum (*Hall*)
Eridotrypa solida (*Hall*)
Eridotrypa striata (*Hall*)
Fenestella elegans *Hall*
Fistulipora crustula *Bassler*
Idiotrypa punctata (*Hall*)
Lioclema asperum (*Hall*)
Lioclema multiporum *Bassler*
Lioclemella maccombi *Bassler*
Loculipora ulrichi *Bassler.*
Monotrypa benjamini *Bassler*
Nematopora minuta (*Hall*)
Nicholsonella florida (*Hall*)
Pachydictya crassa (*Hall*)
Phylloporina asperato-striata (*Hall*)
Polypora incepta (*Hall*)
Rhopalonaria attenuata *Ulrich and Bassler*
Semicoscinium tenuiceps (*Hall*)
Stictotrypa punctipora (*Hall*)
Thamniscus dichotomus (*Hall*)
Trematopora spiculata (*Hall*)
Trematopora tuberculosa *Hall*

Vermes—

Cornulites arcuatus *Conrad*

Pelecypods—

Liopteria subplana (*Hall*)
Pterinea emacerata (*Conrad*)
Pterinea undata (*Emmons*)

Gastropods—

Diaphorostoma niagarensis (*Hall*)
Platyceras niagarensis *Hall*

Pteropods—

Conularia longa *Hall*
Conularia niagarensis *Hall*

Trilobites—

Calymmene niagarensis *Hall*
Ceraurus niagarensis *Hall*
Dalmanites limulurus (*Green*)
Homalonotus dephinocephalus (*Green*)
Illaenus ioxus *Hall*
Lichas boltoni (*Bigsby*)

3, 4 and 5. Clinton Formation.—The recognition of the Rochester shale as a stratigraphic unit compels the adoption of another name for the strata between the shale and the underlying Medina sandstone. These strata are the equivalent of those in the Niagara section referred to the Clinton, and the fossils show that they are closely related in time to the Rochester. The *Pentamerus* bed at the base of the formation contains the same form of *P. oblongus* seen in the Clinton of Rochester, New York. Few fossils are to be obtained except at the top, in the heavy 4-foot bed (1·2 m.), and at the base, in the *Pentamerus* zone. The species are nearly all brachiopods as below:—

Atrypa reticularis (Linn)
Camarotoechia neglecta (*Hall*)
Leptæna rhomboidalis (*Wilckens*)
Orthis flabellites *Foerste*
Pentamerus oblongus *Sowerby*
Spirifer radiatus *Sowerby*
Stricklandinia canadensis *Billings*
Whitfieldella cf. cylindrica *Hall*
Whitfieldella intermedia *Hall*
Whitfieldella nitida *Hall*
Whitfieldella nitida oblata *Hall*
Dawsonoceras annulatum americanum (*Foord*)
Platyceras sp.

6 and 7. Medina formation.—The Upper Medina may be best seen on the west side of the ravine of Forty Mile creek. The grey band lies almost immediately below the *Pentamerus* zone and presents excellent examples of *Daedalus* (*Arthrophycus*) *archimedes* Ringueberg. Splendid examples of *Arthrophycus alleghaniensis* Harlan, may be obtained on the under side of the sandstone slabs. The typical Medina fossil, *Lingula cuneata* Conrad, occurs in the lower part of the formation.

8, 9 and 10. Cataract formation.—The Cataract formation was first officially defined by Professor Charles Schuchert of Yale University at the 1912 meeting of the Geological Society of America. The reading of Professor Schuchert's paper evoked considerable discussion. Dr. E. O. Ulrich being strongly of the opinion that the formation should be included in the Medina or at least in the "*Medinian*." It is to be understood therefore that all American

geologists are not prepared to accept the classification herein adopted.

Cataract shales and limestones are not well exposed on the west side of the ravine of Forty Mile creek, but in the cliff on the east side the contacts may be observed. Owing to a heavy talus, this location is not as good a collecting ground as at Stony Creek, between Grimsby and Hamilton, or at Hamilton itself. The more common species are given below; for a more complete list see the guide to Excursion B 4.

Corals—
- Favosites cf. niagarensisa (*Hall*)
- Zaphrentis bilateralis (*Hall*)

Hydrozoans—
- Clathrodictyon vesiculosum *Nicholson and Murie*
- Retiolites venosus *Hall*

Brachiopods—
- Anoplotheca planoconvexa (*Hall*)
- Atrypa reticularis (*Linn*)
- Atrypa cf. rugosa *Hall*
- Camarotœchia neglecta (*Hall*)
- Dalmanella elegantula (*Dalman*)
- Hebertella fausta *Foerste*
- Leptæna rhomboidalis (*Wilckens*)
- Lingula lingulata *Hall and Clarke*
- Lingula cf. clintoni *Vanuxem*
- Lingula oblata *Hall*
- Lingula oblonga *Hall*
- Orthis flabellites *Foerste*
- Platystrophia biforata (*Schlotheim*)
- Plectambonites transversalis (*Wahlenberg*)
- Rhipidomella cf. circulus (*Hall*)
- Rhipidomella hybrida (*Sowerby*)
- Schuchertella sp.
- Whitfieldella sp.

Bryozoans—
- Clathropora frondosa *Hall*
- Helopora fragilis *Hall*
- Phænopora constellata *Hall*
- Phænopora ensiformis *Hall*
- Phænopora explanata *Hall*
- Rhinopora verrucosa *Hall*

Vermes—
- Cornulites distans *Hall*

Pelecypods—
- Posidonomya cf. alata (*Hall*)
- Tellinomya sp.

Gastropods—
- Bucania trilobita (*Conrad*)
- Cyclonema sp.
- Platyostoma sp.

Trilobites—
- Acidaspis sp.
- Encrinurus sp.

Section at Hamilton.

The electric railway between Grimsby and Hamilton runs close along the foot of the escarpment thus affording interesting glimpses of the cuesta to the left and the fruit lands to the right. At Stony creek an excellent section is presented, at which Cataract fossils may be obtained in abundance. The section at Hamilton is best seen by ascending the escarpment at the "Jolly Cut." This section is similar to that at Grimsby, but the various formations appear in different thicknesses, the Rochester and Clinton being greatly reduced.

		Thickness		Elevation	
		Ft.	Met.	Ft.	Met.
Lockport	1—Chert beds	12	3·6	650	197·6
	2—Chert with shaly partings	3	0·9		
	3—Crystalline grey dolomite with green shaly partings	2·5	0·5		
	4—Heavy dark dolomite with black shaly partings	4·5	1·3		
Rochester	5—Limestone and shales	4·5	1·3		
	6—Ferruginous band				
	7—Shale and limestone	10	3·0		
Clinton	8—Heavy dolomite	4	1·2		
	Thin limestones	4	2·1		
	9—Pentamerus band	2·5	0·7		
Medina	10—Grey sandstone and shale	12	3·6	600	182·4
Cataract	11—Red and grey shales	70	21·3		
	12—Blue limestone	10	3·6		
	13—Grey sandstone	10	3·6		
Queenston	14—Red shales			498	151·4
	Railway station, Hamilton			253	76·9

1, 2, 3 and 4. Lockport dolomite and chert.—While certain differences in the fossil content of these beds are to be observed, the general fauna is much the same throughout. Numerous Lithistid sponges occur in the chert beds, of which the more common are:

Actylospongia præmorsa *Goldfuss.*
Aulocopina granti *Billings.*

Dendroid Graptolites are very characteristic and numerous: Bassler recognizes 11 genera and 52 species. Common species are: —

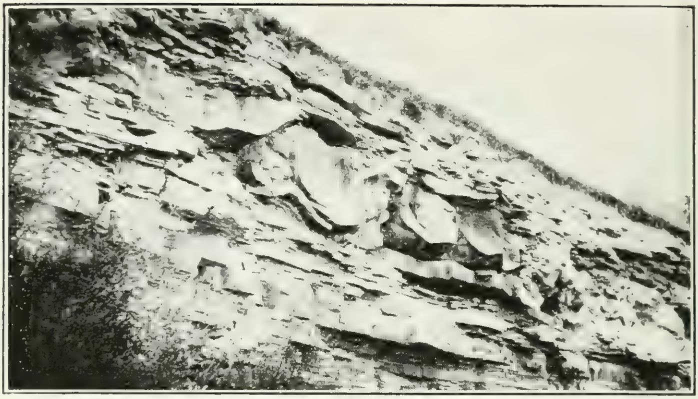
Acanthograptus granti *Spencer*
Calyptograptus cyathiformis *Spencer*
Dictyonema crassibasale *Gurley*
Dictyonema retiforme *Hall*
Inocaulus plumosus *Hall*

Brachiopods are abundant and are represented by the following species:—

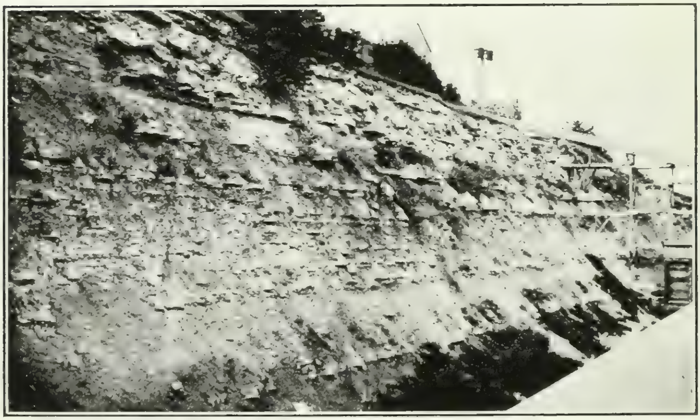
Atrypa reticularis (*Linn.*)
Camarotœchia neglecta (*Hall*)
Crania siluriana *Hall.*
Dalmanella elegantula (*Dalman*)
Delthyris sulcata (*Hisinger*)
Ditcyonella corallifera *Hall*
Dictyonella reticulata *Hall*
Leptæna rhomboidalis (*Wilckens*)
Lingulops granti *Hall and Clarke*
Pholidops squamiformis *Hall*
Plectambonites transversalis (*Wahlenberg*)
Rhipidomelia hybrida (*Sowerby*)
Schizotreta tenuilamellata (*Hall*)
Schuchertella subplana (*Conrad*)
Spirifer niagarensis (*Conrad*)
Stropheodonta profunda *Hall*
Strophonella patenta (*Hall*)
Strophonella cf. striata *Hall*

The Bryozoa in these beds are not well preserved and are difficult of recognition. The common species follow:—

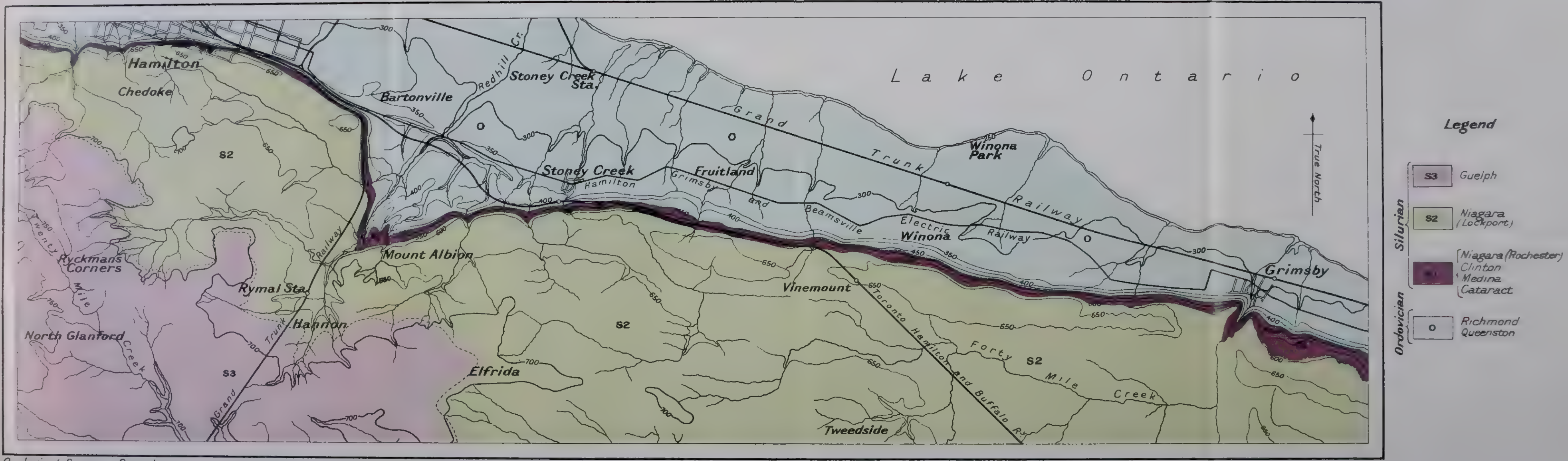
Ceramopora imbricata *Hall*
Ceramoporella irregularis (*Whitfield*)
Drymotrypa diffusa (*Hall*)
Fenestella elegans *Hall*
Semicoscinium tenuiceps (*Hall*)



Medina sandstone with "pillow structure" lying unconformably on Cataract shales, Jolly Cut, Hamilton, Ontario.



Section of upper Cataract shales with overlying Medina sandstone, Jolly Cut, Hamilton, Ontario.



Geological Survey, Canada.

Route map between **Hamilton** and **Grimsby**

Miles
1 ½ 0 1 2 3
Kilometres
1 ½ 0 1 2 3 4 5

Orthoceras bartonense Spencer, is fairly common and numerous tails of *Dalmanites limulurus* (Green) occur. Species of *Conularia* are not infrequent.

5, 6 and 7.—These beds probably represent the Rochester shales but they are not typical either in petrographic character or fossil content. The characteristic Rochester echinoderms have not been found here but *Rhynchotreta cuneata americana* and some of the Bryozoa and Graptolites of the Rochester occur.

8 and 9.—These beds, which represent the Clinton formation, do not differ essentially from those at Grimsby.

10.—The Medina sandstone is less well defined in this section than at Grimsby, but it shows some interesting bedding features.

11, 12 and 13.—The Cataract limestone and shales may be seen in the excavations along the Jolly Cut road, but a better locality for collecting is presented by the quarries farther east. The fossils are the same as those already given for Grimsby.

14.—The Queenston shales are not well exposed along the Jolly Cut road but they may be seen farther west and at numerous places along the line of the rai lway

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LIST OF ILLUSTRATIONS.

Maps.

Drawings and Sections.

Photographs.

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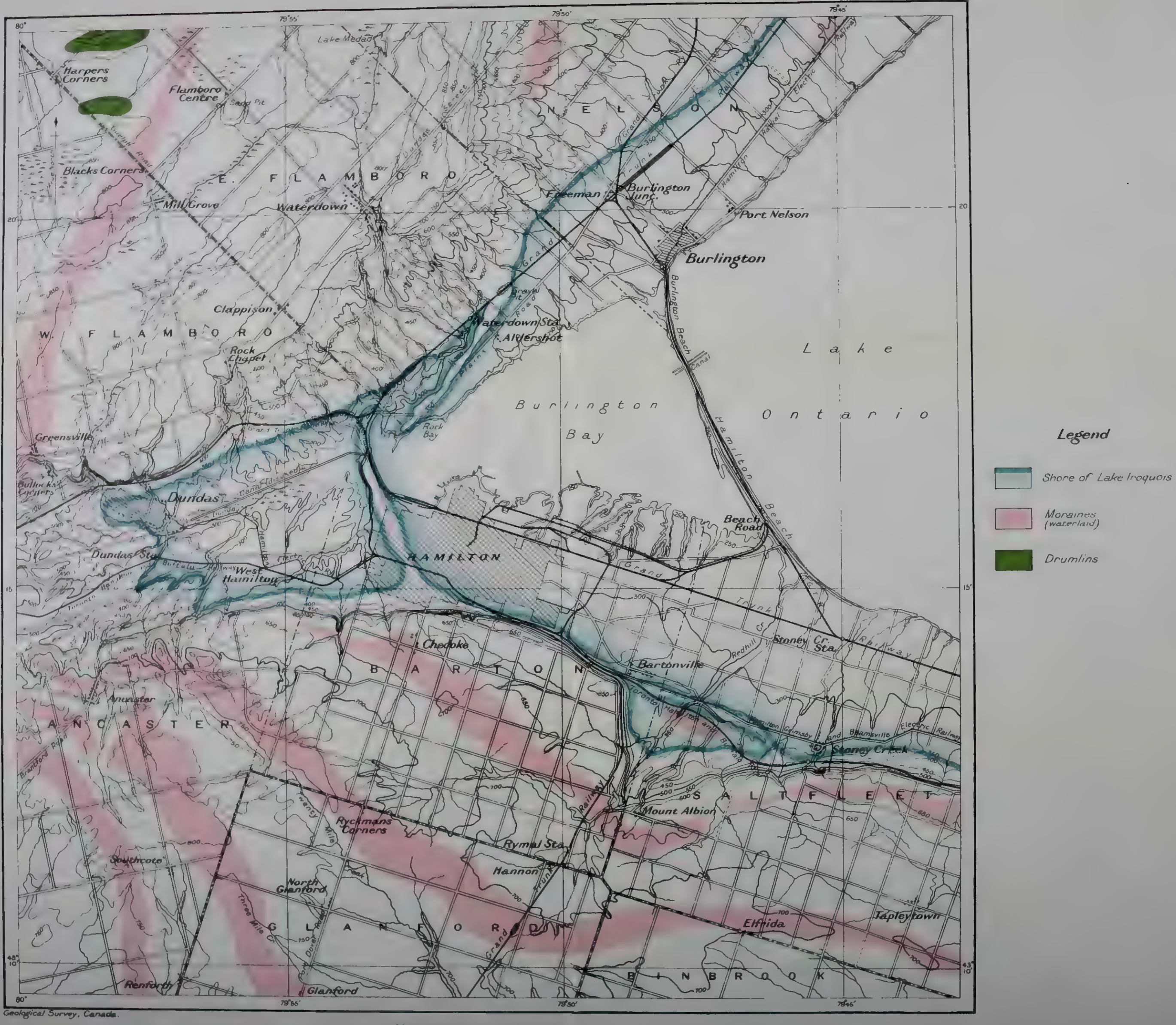

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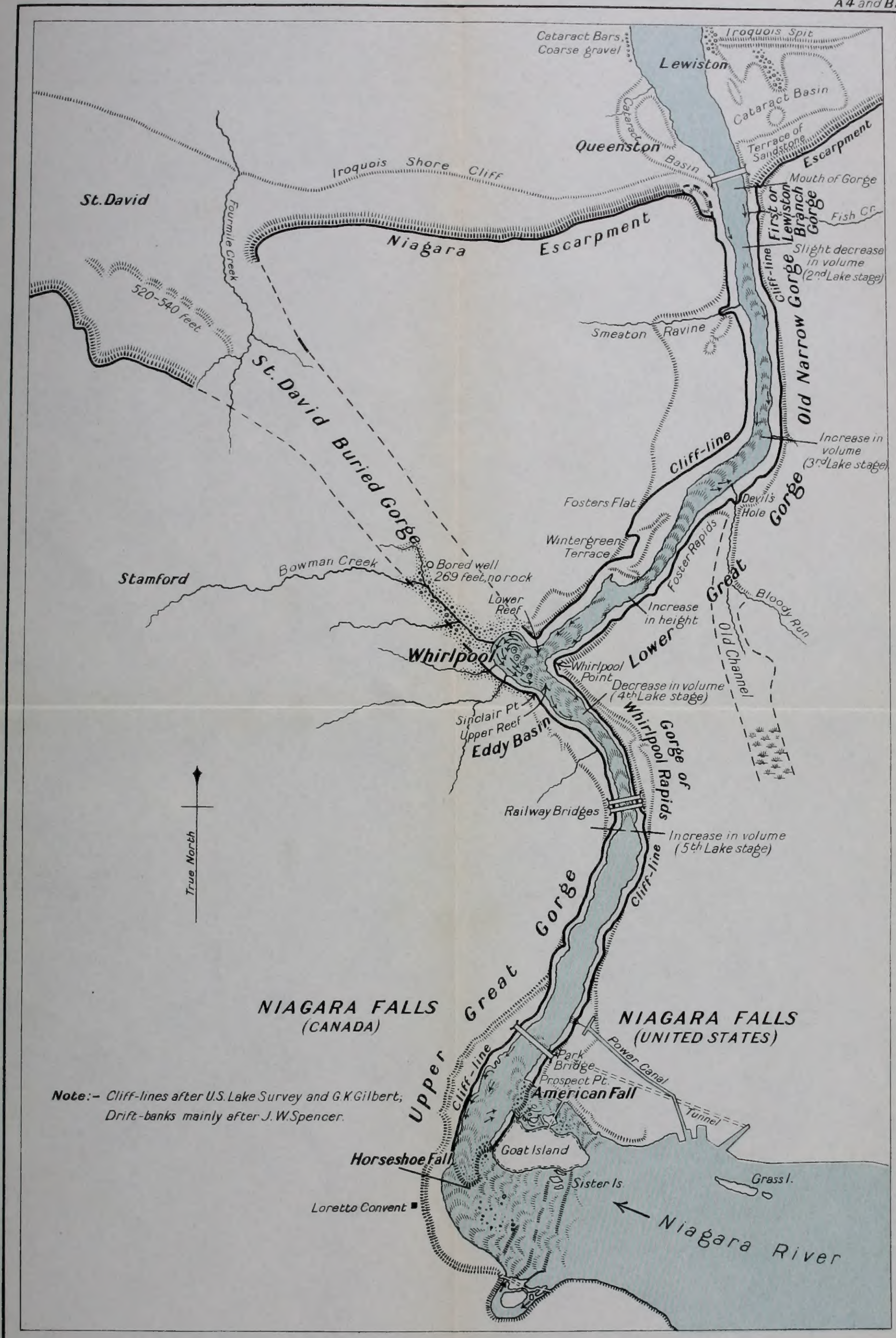
Hamilton and Vicinity

Miles

Kilometres



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Niagara Gorge